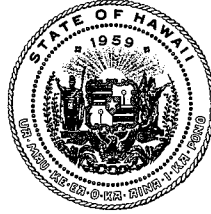


DAVID Y. IGE
GOVERNOR OF HAWAII



STATE OF HAWAII
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ENGINEERING

FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE PARKS

October 16, 2015

TO: Jessica Wooley, Director
Office of Environmental Quality Control

FROM: Suzanne D. Case, Chairperson 
Department of Land and Natural Resources

SUBJECT: Request for publication of "Nāpu'u Conservation Project: Draft Habitat Conservation Plan for Game Management at Pu'u Wa'awa'a and Pu'u Anahulu" in the November 8, 2015 Environmental Notice



We respectfully request publication of the "Nāpu'u Conservation Project: Draft Habitat Conservation Plan for Game Management at Pu'u Wa'awa'a and Pu'u Anahulu" in the November 8, 2015 Environmental Notice.

Please find enclosed a complete OEQC publication form, one hard copy of the document and one electronic copy of each document in PDF form on CD.

Please contact Division of Forestry and Wildlife, Wildlife Program Manager James Cogswell at james.m.cogswell@hawaii.gov or 808-587-4187 with any questions.

Publication Form
The Environmental Notice
Office of Environmental Quality Control

Instructions: Please submit one hardcopy of the document along with a determination letter from the agency. On a compact disk, put an electronic copy of this publication form and a PDF of the EA or EIS. Mahalo.

Name of Project: Nāpu‘u Conservation Project

Applicable Law: HRS Chapter 195D

Type of Document: Draft Habitat Conservation Plan

Island: Hawai‘i Island

District: North Kona

TMK: TMKs 3-7-1-003-001, 3-7-1-004-001, 3-7-1-004-018, 3-7-1-001-001, 3-7-1-001-004, 3-7-1-001-006, 3-7-1-001-007, 3-7-1-002-001, and 3-7-1-002-013

Permits Required: Incidental Take License

Name of Applicant or Proposing Agency:

Department of Land and Natural Resources

Division of Forestry and Wildlife

1151 Punchbowl Street Room 325

Honolulu, Hawaii, 96813

808 587 4187

Approving Agency or Accepting Authority:

Department of Land and Natural Resources Board of Land and Natural Resources

1151 Punchbowl Street

Honolulu, Hawaii, 96813

808 587 0400

Consultant

N/A

Project Summary: Summary of the direct, indirect, secondary, and cumulative impacts of the proposed action (less than 200 words).

The Department of Land and Natural Resources Division of Forestry and Wildlife has been developing a Habitat Conservation Plan (HCP) for land managed primarily for maintenance of non-native game mammal populations for hunting, in addition to conservation of native habitat in the Pu‘u Wa‘awa‘a Forest Reserve and the Pu‘u Anahulu Game Management Area, in North Kona, on the island of Hawai‘i. The development of this HCP will provide for the incidental take of the following fifteen threatened and endangered plants and one endangered insect: *Asplenium peruvianum* var. *insulare*, Uhiuhi (*Mezoneuron kawaiense*), Kauila (*Colubrina oppositifolia*), Honohono (*Haplostachys haplostachya*), Ma‘o hau hele (*Hibiscus brackenridgei* ssp. *brackenridgei*), Koki‘o (*Kokia drynarioides*), *Neraudia ovata*, ‘Aiea (*Nothocestrum breviflorum*), Hala pepe (*Pleomele hawaiiensis*), Po‘e (*Portulaca sclerocarpa*), Hawaiian Catchfly (*Silene lanceolata*), Pōpolo kū mai (*Solanum incompletum*), *Stenogyne angustifolia*, A‘e (*Zanthoxylum dipetalum* var. *tomentosum*), and A‘e (*Zanthoxylum hawaiiense*) and the Blackburn’s sphinx moth (*Manduca blackburni*). The HCP outlines provisions for net benefit to the covered species and environment, and contributes to the recovery of each of these species.

The public is encouraged to comment on the draft HCP. Please send comments to:

Department of Land and Natural Resources
Division of Forestry and Wildlife
1151 Punchbowl Street Room 325
Honolulu, HI, 96813
Attention: Conservation Initiatives Coordinator Afsheen Siddiqi

Or email comments to: Afsheen.A.Siddiqi@hawaii.gov

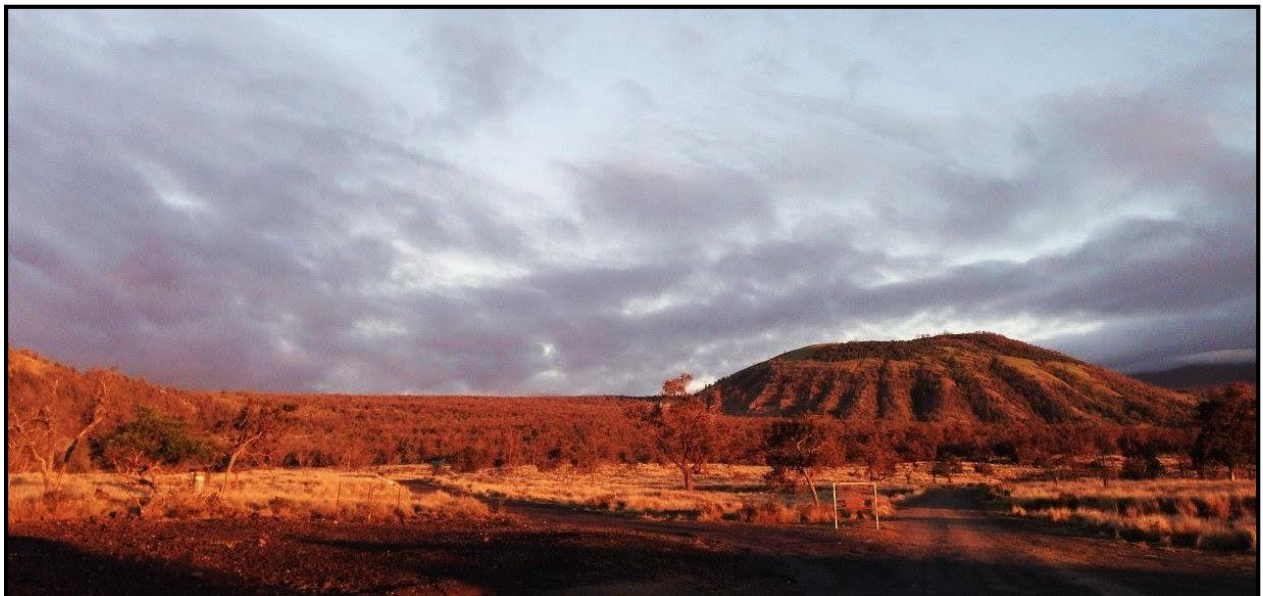
Public comments should be received by March 7, 2016.

The Division of Forestry and Wildlife will also hold a public hearing on the island of Hawai'i to receive public comments on the draft Habitat Conservation Plan. The date and location of the public hearing will be made available to the public via legal notice.

Draft Habitat Conservation Plan for Game Management at Pu‘u Wa‘awa‘a and Pu‘u Anahulu

Nāpu‘u Conservation Project

10/20/2015



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EXECUTIVE SUMMARY

The Hawai'i Department of Land and Natural Resources (DNLR), through the Division of Forestry and Wildlife (DOFAW), manages lands in the Pu'u Wa'awa'a Forest Reserve (PWWFR) and the Pu'u Anahulu Game Management Area (PAHGMA), in North Kona, on the Island of Hawai'i. Nāpu'u (The-hills) is the historical name used for the ahupua'a of Pu'u Wa'awa'a and Pu'u Anahulu (Maly and Maly 2006) and is the title we have chosen to represent the conservation project that incorporates the actions of this Habitat Conservation Plan (HCP). The area is home to native bird, plant and invertebrate species as well as non-native game mammal and bird species. Current land management in the Pu'u Anahulu Game Management Area is primarily for maintenance of non-native game mammal populations for hunting, in addition to conservation of native habitat. Pu'u Wa'awa'a Forest Reserve is a multi-use area where management includes game population maintenance for hunting, natural resource conservation and restoration, and other activities such as cattle grazing and trail use.

This Habitat Conservation Plan is intended to consider and mitigate for the potential impacts from DOFAW game mammal management activities on endangered species within the Pu'u Wa'awa'a and Pu'u Anahulu areas (Plan Area 103,988¹ acres). Potential negative impacts on Covered Plant species are primarily in the form of direct take from grazing, browsing, and trampling associated with the management of game mammals and cattle in the Plan Area. This plan as a whole intends to provide for avoidance and minimization measures, and mitigation which will provide net benefit to the species and environment, above and beyond any incidental take of protected species which may occur due to Plan actions. This plan will also utilize the grazing activities of game mammals and cattle to reduce fuel loads outside of planned and existing exclosures to prevent wildland fire which is a primary threat to dryland forests.

Covered Species likely to be impacted by Plan activities were identified through consideration of previous botanical and wildlife surveys, as well as on-the-ground botanical and wildlife surveys performed as part of the HCP planning process. The development of this HCP will provide for the incidental take of one endangered insect, Blackburn's sphinx moth (*Manduca blackburni*) and fifteen threatened and endangered plants: *Asplenium peruvianum* var. *insulare*, Hala pepe (*Chrysodracon hawaiiensis*), Kauila (*Colubrina oppositifolia*), Honohono (*Haplostachys haplostachya*), Ma'o hau hele (*Hibiscus brackenridgei* ssp. *brackenridgei*), Koki'o (*Kokia drynarioides*), *Neraudia ovata*, 'Aiea (*Nothoctrum breviflorum*), Uhiuhi (*Mezoneuron kavaiense*) Po'e (*Portulaca sclerocarpa*), Hawaiian Catchfly (*Silene lanceolata*), Pōpolo kū mai (*Solanum incompletum*), Creeping Mint (*Stenogyne angustifolia*), A'e (*Zanthoxylum dipetalum* var. *tomentosum*), and A'e (*Zanthoxylum hawaiiense*).

A model has been developed to estimate the density of individuals of each covered plant species within the Plan Area. These estimates are used to quantify the level of take anticipated for the covered plant species over the course of the HCP. All plant species located outside of fenced units are considered subject to take.

Blackburn's sphinx moth (*Manduca blackburni*) is the only insect species that has been identified as potentially impacted by activities within the Plan Area, from removal of non-native tree tobacco (*Nicotiana glauca*) from fuelbreaks to allow access for management and hunting activities. Clearing of fuelbreaks and roads is critical for overall fire suppression in the Plan

¹ Plan Area acreage is based on TMK acreage.

Area. Data from larval surveys are used to estimate take of larvae in the Plan Area as well as guide avoidance, minimization, and mitigation actions.

The focus for the stabilization of threatened and endangered species occurring within the Plan Area will be on restoration of functional communities. These communities should support not only stable Covered Species populations, but represent fully functional (insofar as possible), self-sustaining communities with minimal dependence on human management.

Exclosures are the most effective tool for the avoidance and minimization of threats from ungulate grazing, browsing, and traffic on plant populations. Currently, 4,181² acres (4 % of Plan Area) are fenced within eleven exclosures across the Plan Area, and additional 4,757 acres (4.5% of Plan Area) are proposed for fencing under this HCP. Take estimates are combined with species stabilization criteria to define mitigation goals for each plant species. Monitoring of compliance and take of protected species, review and implementation of adaptive management measures are required by law and to ensure that the HCP is implemented correctly, efficiently, and effectively for the species, environment, and all parties concerned.

² Fenced unit acreage based on GIS acreage.

Table 0.1 Summary of Avoidance/Minimization and Mitigation Measures to Offset the Requested Take of Covered Species.

Avoidance and Minimization within the Plan Area

1. Install all avoidance and minimization exclosures by Year 8 (See Section 4.3.6.2).
 - a. Remove ungulates from within exclosures within first year of fencing (this may be dependent upon unit size).
 - b. Invasive species control:
 - i. Reduce overall alien cover by 50% around Covered Species by Year 8.
 - ii. Conduct rodent and slug control or other threats as needed.
 - iii. Maintain fuelbreaks around fencelines semi-annually.
 - iv. Conduct quarterly fence line and ungulate ingress checks.
 - c. Census of all Covered Species within a unit within first year of fencing.
 - d. A monitoring plan for *in situ* populations will be developed by Year 3.

Mitigation within the Plan Area

1. Install all mitigation exclosures by Year 15 (See Section 6.1).
2. Collection of propagules from *in situ* plant populations
 - a. Identify propagule collection needs by Year 3.
 - b. Collect propagules from each known plant population by Year 5 (see Section 6.5).
3. Collection of propagules from *in situ* plant populations
 - a. Identify propagule collection needs by Year 3.
 - b. Collect propagules from each known plant population by Year 5 (see Section 6.5).
4. Propagation of propagules for all Covered Species at Volcano Rare Plant Facility, DOFAW Waimea Tree Nursery, or PWW on-site nursery.
5. Outplanting of no less than the mitigation target for each Covered Species within appropriate exclosures in the Plan Area (see Section 6.1).
 - a. Individuals (or clusters of individuals) will be tagged and documented with GPS.
 - b. GPS location information, accession numbers, plant status, and any other pertinent information will be inputted into a database for long-term monitoring.
 - c. Site preparation consists of removal of non-native vegetation, through weed whacking, herbicide, and/or manual pulling.
 - d. A minimum of 50% of each Covered Species mitigation goal (Table 6.18) will be outplanted by Year 8.
 - e. A minimum of 100% of each Covered Species mitigation goal (Table 6.18) will be outplanted by Year 15.
 - f. A monitoring plan for mitigation populations will be developed by Year 3.
 - g. Mitigation populations (individuals or clusters of individuals) will be monitored annually.
6. Management of outplanted populations for 25 years:
 - a. Outplanted individuals are watered upon planting and follow up watering is provided as needed in the first 3 months.
 - b. Pest control (aphids etc) will be conducted as needed.
 - c. Removal of non-native species from outplanting areas:

- i. Remove 90% of fountain grass and kikuyu grass from within 3 meters of an individual (or cluster of) outplants
- ii. Maintain a 25-50 m buffer of less than 50% invasive grass coverage around an individual (or cluster of) outplants.
- iii. Weeding is scheduled as needed.

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ACRONYMS

AS	Apparently Secure
ATV	All-terrain Vehicle
BLNR	Board of Land and Natural Resources
BSM	Blackburn's Sphinx Moth
CE	Critically Endangered
CH	Critical Habitat
CTTIA	Core Tree Tobacco Infestation Area
DDIT	DLNR-DOFAW Implementation Team
DLNR	Department of Land and Natural Resources
DOFAW	Division of Forestry and Wildlife
EA	Environmental Assessment
ESA	Endangered Species Act
ESRC	Endangered Species Recovery Committee
FBS	Forest Bird Sanctuary
FR	Forest Reserve
FWS	Fish and Wildlife Service
GIS	Geographic Information System
GMA	Game Management Area
GPS	Global Positioning System
HCP	Habitat Conservation Plan
HEPA	Hawai'i Environmental Policy Act
HETF	Hawai'i Experimental Tropical Forest
HPPRCC	Hawai'i and Pacific Plants Recovery Coordinating Committee
HRPRG	Hawai'i Rare Plant Restoration Group
HRS	Hawai'i Revised Statutes
HVNP	Hawai'i Volcanoes National Park
ICUN	International Union for Conservation of Nature
ITL	Incidental Take License
ITP	Incidental Take Permit
NAR	Natural Area Reserve
NEPA	National Environmental Policy Act
PAHGMA	Pu'u Anahulu Game Management Area
PEPP	Plant Extinction Prevention Program
PEP	Species that has fewer than 50 wild plants remaining (PEPP designation)
POP	Potentially PEP Species (PEPP designation)
PTA	Pōhakuloa Training Area
PWW	Pu'u Wa'awa'a
PWWFR	Pu'u Wa'awa'a Forest Reserve
PWWMP	Pu'u Wa'awa'a Management Plan
ROI	Rare on Island (PEPP designation)
SOC	Species of Concern
TMK	Tax Map Key
UH	University of Hawai'i
USDA	United States Department of Agriculture
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
UTM	Universal Transverse Mercator

1.0 INTRODUCTION AND PLAN OVERVIEW

The Hawai‘i Department of Land and Natural Resources (DNLR), through the Division of Forestry and Wildlife (DOFAW), manages lands in the Pu‘u Wa‘awa‘a Forest Reserve (PWWFR) and the Pu‘u Anahulu Game Management Area (PAHGMA), in North Kona, on the Island of Hawai‘i. Pu‘u Wa‘awa‘a is often coupled with its neighbor to the north, the ahupua‘a of Pu‘u Anahulu, the natural and cultural resources of these lands, as well as the familial associations, have been shared together since the earliest of Hawaiian times, and the relationship of the native families of the land remains strong to this present day (Maly and Maly 2006). These lands are collectively called “Nāpu‘u”³, and share common threads of environment, traditions, land tenure, and familial and cultural attachments. The Nāpu‘u Conservation Project represents the the actions defined in this Habitat Conservation Plan.

The proposed Plan Area (total of 103,988 acres)⁴ is on the western side of North Kona, includes the Pu‘u Wa‘awa‘a Forest Reserve (TMKs 3-7-1-003-001, 3-7-1-004-001 and 3-7-1-004-018) and Pu‘u Anahulu Game Management Area (TMKs 3-7-1-001-001, 3-7-1-001-004, 3-7-1-001-006, 3-7-1-001-007, 3-7-1-002-001, and 3-7-1-002-013)(Figure 1.1). The area is home to native and non-native game, bird, plant and invertebrate species. Current land management in the Pu‘u Anahulu Game Management Area is primarily for maintenance of non-native game mammal populations for hunting, in addition to conservation of native habitat. Pu‘u Wa‘awa‘a Forest Reserve is a multi-use area where management includes game population maintenance for hunting, and natural resource conservation and restoration, as well as other activities such as cattle grazing and trail use. It is anticipated that these activities have the potential to result in the incidental take of one animal species, Blackburn’s sphinx moth (*Manduca blackburni*), and 15 state and federally listed plant species: *Asplenium peruvianum* var. *insulare*, Hala pepe (*Chrysodracon hawaiiensis*), Kauila (*Colubrina oppositifolia*), Honohono (*Haplostachys haplostachya*), Ma‘o hau hele (*Hibiscus brackenridgei* ssp. *brackenridgei*), Koki‘o (*Kokia drynarioides*), *Neraudia ovata*, ‘Aiea (*Nothocestrum breviflorum*), Uhiuhi (*Mezoneuron kavaiense*) Po‘e (*Portulaca sclerocarpa*), Hawaiian Catchfly (*Silene lanceolata*), Pōpolo kū mai (*Solanum incompletum*), Creeping Mint (*Stenogyne angustifolia*), A‘e (*Zanthoxylum dipetalum* var. *tomentosum*), and A‘e (*Zanthoxylum hawaiiense*). Potential negative impacts on these listed plant species are primarily in the form of direct take from grazing, browsing, and trampling associated with the management of game mammals and cattle in the Plan Area. Potential impacts to Blackburn’s sphinx moth larvae and eggs are from the clearing and maintenance of fuelbreaks and four-wheel drive access roads. No other listed, proposed, or candidate plant or animal species are anticipated to be taken by Plan activities.

State (HRS §195-D) law requires provisions for protected species impacted by Plan actions and therefore, DLNR is seeking an Incidental Take License (ITL) in accordance with Chapter 195-D, Hawai‘i Revised Statutes. This permit is issued by the DLNR. The Habitat Conservation Plan (HCP) supports the issuance of this permit, and describes how the Applicant will avoid, minimize, mitigate, and monitor the incidental take of endangered species that may occur in the Plan Area during the management and maintenance of non-native game mammals and hunting

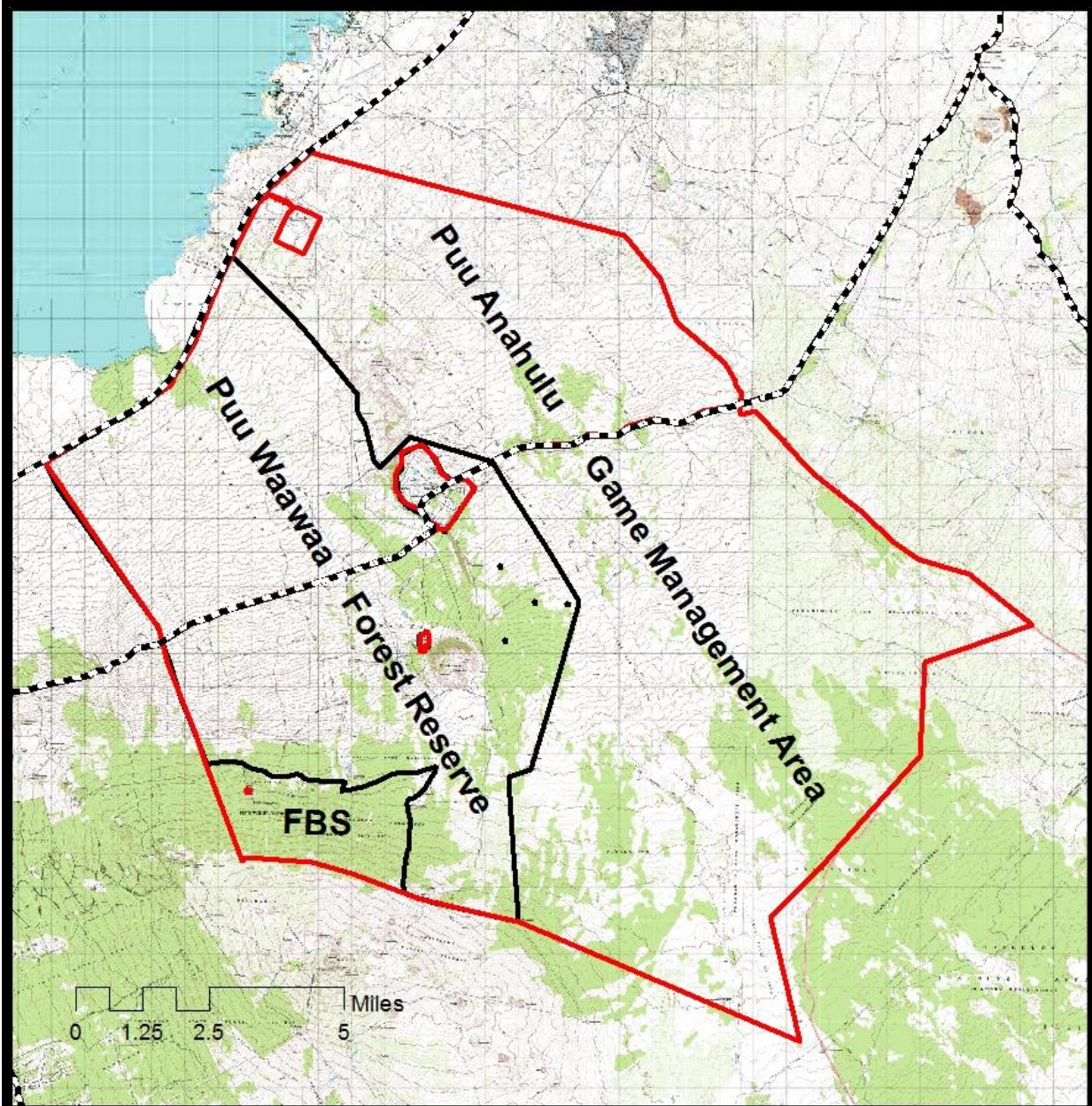
³ Nāpu‘u (The-hills) is a general name for the hilly region of Pu‘u Wa‘awa‘a and Pu‘u Anahulu. The name also includes variations, such as Nā-pu‘u-pū‘alu (The-loose, crumpled, or folded-hills) or Nā-pu‘u-pū‘alu-kinikini (The-many-folded-hills), which describe the topography - the rolling folds of the hills.

⁴ Calculated based on TMK tax acreage.

within the PWWFR and PAHGMA. The HCP integrates components of the current Pu‘u Wa‘awa‘a Management Plan (PWWMP) (2003), and outlines a monitoring protocol to determine successful mitigation for each species throughout the duration of the Plan. Additionally, this HCP incorporates adaptive management provisions to allow for modifications to the mitigation and monitoring measures as knowledge is gained during implementation.

Timely implementation of this plan should provide net benefit to the species and environment, and will increase the likelihood of recovery of the endangered and threatened species that are the focus of the plan. This plan, with an approved Incidental Take License for anticipated take of these species, should address applicable requirements under State endangered species law.

DRAFT



Habitat Conservation Plan Area



- Plan Area
- - - Highway
- Property Boundaries



Figure 1.1 Plan Area (103,988 acres), including Pu‘u Wa‘awa‘a forest reserve, Pu‘u Anahulu game management area, and the Pu‘u Wa‘awa‘a forest bird sanctuary, North Kona, island of Hawai‘i. Internal red outlines signify private inholdings and are excluded from the Plan Area.

1.1 REGULATORY SETTING

1.1.1 Endangered Species Act

The ESA and its implementing regulations prohibit the take of any fish or wildlife species that is federally listed as threatened or endangered without prior approval pursuant to either Section 7 or Section 10 (a)(1)(B) of the ESA. Section 9 of the ESA defines “take” as “to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct.” The term harm means an act that actually kills or injures a federally listed wildlife species, and may include significant habitat modification or degradation (50 Code of Federal Regulations [CFR] section 17.3). In addition, Section 9 of the ESA details generally prohibited acts and Section 11 provides for both civil and criminal penalties for violators regarding species federally listed as threatened or endangered.

ESA section 4(f) requires the USFWS to develop and implement recovery plans for the conservation and survival of listed species. Recovery plans must describe specific management actions, establish objectives and measurable criteria for delisting, and estimate the time and cost to carry out measures needed to achieve recovery. The USFWS has developed recovery plans for all the species covered under this HCP (USFWS 1993, 1996b, 1998b, a, 1999, 2003b). The biological goals and objectives identified in Section 4.0 are consistent with these recovery plans.

This HCP is being written to fulfill requirements under the state of Hawaii endangered species laws for the issuance of an Incidental Take License (ITL) for the incidental take of endangered species (described in more detail below). An HCP is needed because project actions may have the potential to result in take of listed species that occur in the Plan Area. Under HRS Chapter 195D-4, DLNR may authorize incidental take through the issuance of an ITL. In support of an application for the ITL, the applicant must prepare an HCP. This document establishes the methods and measures of success required to meet the conservation needs of listed species potentially impacted by the project. Additionally, to ensure compliance under the Federal ESA, DOFAW has initiated formal consultation under Section 7 of the ESA for potential take of Blackburn’s sphinx moth resulting from road clearing activities in the Plan Area financed by federal funding. If in the future consultation under the Federal ESA with regards to take of listed species addressed in the State HCP becomes necessary, DOFAW will initiate formal consultation under Section 7 to ensure compliance with all Federal ESA requirements.

1.1.2 Chapter 195D, Hawai‘i Revised Statutes

The purpose of Chapter §195D of Hawai‘i Revised Statutes (HRS) is “to ensure the continued perpetuation of indigenous aquatic life, wildlife, and land plants, and their habitats for human enjoyment, for scientific purposes, and as members of ecosystems...” (§195D-1). §195D-4 states that any endangered or threatened species of fish or wildlife recognized by the ESA shall be so deemed by State statute. Like the ESA, the unauthorized “take” of such endangered or threatened species is prohibited [§195D-4(e)]. Under §195D-4(g), the Board of Land and Natural Resources (BLNR), after consultation with the State’s Endangered Species Recovery Committee (ESRC), may issue a temporary Incidental Take License (subsequently referred to as an “ITL”) to allow a take otherwise prohibited if the take is incidental to the carrying out of an otherwise lawful activity.

In order to qualify for an ITL, the following must occur:

- The Applicant minimizes and mitigates the impacts of the take to the maximum extent practicable.
- The Applicant guarantees that adequate funding for the HCP will be provided.
- The Applicant posts a bond, provides an irrevocable letter of credit, insurance, or surety bond, or provides other similar financial tools, including depositing a sum of money in the endangered species trust fund created by §195D-31, or provides other means approved by BLNR, adequate to ensure monitoring of the species by the State and to ensure that the applicant takes all actions necessary to minimize and mitigate the impacts of the take.
- The HCP increases the likelihood that the species will survive and recover.
- The HCP takes into consideration the full range of the species on the island so that cumulative impacts associated with the take can be adequately assessed.
- The activity permitted and facilitated by the license to take a species does not involve the use of submerged lands, mining, or blasting.
- The cumulative impact of the activity, which is permitted and facilitated by the license, provides net environmental benefits.
- The take is not likely to cause the loss of genetic representation of an affected population of any endangered, threatened, proposed, or candidate plant species.

Section 195D-21 outlines the requirements of HCPs. According to this section, HCPs submitted in support of an ITL application shall:

1. Identify the geographic area encompassed by the HCP; the ecosystems, natural communities, or habitat types within the Plan Area that are the focus of the HCP; and the endangered, threatened, proposed, and candidate species known or reasonably expected to be present in those ecosystems, natural communities, or habitat types in the Plan Area.
2. Describe the activities contemplated to be undertaken within the Plan Area with sufficient detail to allow the department to evaluate the impact of the activities on the particular ecosystems, natural communities, or habitat types within the Plan Area that are the focus of the HCP.
3. Identify the steps that will be taken to minimize and mitigate all negative impacts, including without limitation the impact of any authorized incidental take, with consideration of the full range of the species on the island so that cumulative impacts associated with the take can be adequately assessed; and the funding that will be available to implement those steps.
4. Identify those measures or actions to be undertaken to protect, maintain, restore, or enhance the ecosystems, natural communities, or habitat types within the Plan Area; a schedule for implementation of the measures or actions; and an adequate funding source to ensure that the actions or measures, including monitoring, are undertaken in accordance with the schedule.
5. Be consistent with the goals and objectives of any approved recovery plan for any endangered species or threatened species known or reasonably expected to occur in the ecosystems, natural communities, or habitat types in the Plan Area.
6. Provide reasonable certainty that the ecosystems, natural communities, or habitat types will be maintained in the Plan Area, throughout the life of the HCP, in

sufficient quality, distribution, and extent to support within the Plan Area those species typically associated with the ecosystems, natural communities, or habitat types, including any endangered, threatened, proposed, and candidate species known or reasonably expected to be present in the ecosystems, natural communities, or habitat types within the Plan Area.

7. Contain objective, measurable goals, the achievement of which will contribute significantly to the protection, maintenance, restoration, or enhancement of the ecosystems, natural communities, or habitat types; time frames within which the goals are to be achieved; provisions for monitoring (such as field sampling techniques), including periodic monitoring by representatives of the department or the ESRC, or both; and provisions for evaluating progress in achieving the goals quantitatively and qualitatively.
8. Provide for an adaptive management strategy that specifies the actions to be taken periodically if the plan is not achieving its goals.

In addition to the above requirements, all HCPs and their actions should be designed to result in an overall net benefit to the threatened and endangered species in Hawai‘i (Section 195D-30).

1.1.3 Chapter 343, Hawai‘i Revised Statutes

DLNR has determined that the approval of an HCP and issuance of an ITL under HRS Chapter §195D will be accompanied by environmental review pursuant to HRS Chapter §343.

1.1.4 National Historic Preservation Act

Section 106 of the National Historic Preservation Act of 1966, as amended (16 U.S.C. Section 40 *et seq.*), requires federal agencies to take into account the effects of their proposed actions on properties eligible for inclusion in the National Register of Historic Places. “Properties” are defined herein as “cultural resources,” which includes prehistoric and historic sites, buildings, and structures that are listed on or eligible for the National Register of Historic Places. An undertaking is defined as a project, activity, or program funded in whole or in part under the direct or indirect jurisdiction of a federal agency; including those carried out by or on behalf of a federal agency; those carried out with federal financial assistance; those requiring a federal permit, license or approval; and those subject to state or local regulation administered pursuant to a delegation or approval by a federal agency. The issuance of an ITP is an undertaking subject to Section 106 of the National Historic Preservation Act. Cultural and archeological resources surveys have been conducted for the Plan. The DLNR will coordinate with the State Historic Preservation Division office on cultural resources and address any potential issues in the EA.

1.2 PLAN DESCRIPTION

1.2.1 Plan History

The PWWFR and lands just northeast within PAHGMA have been identified as the Plan Area (103,988 acres) for the purposes of this HCP. In 2003, BLNR approved in concept a *Management Plan for the Ahupua‘a of Pu‘u Wa‘awa‘a and the Makai Lands of Pu‘u Anahulu* (PWWMP). Currently, the lands within the Plan Area are being managed for grazing of non-native mammals, fire management, natural resource management, and public hunting according to the guidelines in the Management Plan. In particular, management for endangered plants involves the construction of fence enclosures, the maintenance of existing enclosures, outplanting, and weed control for 30 conservation units ranging in size from five to approximately 4,000 acres for a total of approximately 8,841 acres (approximately 8.5 % of the Plan Area (103,988 acres)). Currently, 4,181 acres comprising eleven enclosures are fenced within the Plan Area. Nineteen new conservation units, an approximate total of 4,757 acres (4.5 % of the Plan Area (103,988 acres)) will be constructed to protect *in situ* plant populations and allow for additional mitigation area for Covered Species. The current and proposed fenced enclosures will function to protect Covered Species as well as serve as outplanting sites for mitigating take of Covered Species found within the Plan Area.

To date, several botanical surveys, Blackburn’s sphinx moth larval surveys (Appendix D), a multi-year game mammal study (Appendix A), a multi-year ecological restoration study (Parsons et al. 2014), and a vegetation monitoring study (Appendix C) have been conducted to identify the location of endangered species within the Plan Area, calculate game mammal home ranges, monitor outplanting success, and measure the effects of ungulates on endangered plants, respectively. Data from botanical surveys were used, in conjunction with moisture and substrate maps and species range data, to estimate Covered Species population size within unsurveyed areas. The survey and predicted values from these studies serve as the basis for avoidance and minimization strategies and mitigation goals.

Data gathered from game mammal home ranges are used to determine the geographic scope of the area of impact, hereafter “Area of Potential Impact (149,228 acres)”. The calculated home ranges for mammals in the Plan Area are 9.35 km² for female sheep, 12 km² for male sheep, and 16.3 km² for goats. The largest of the three home ranges (16.3 km² for goats, or 2.25 km diameter) was used to calculate the Area of Potential Impact. The Area of Potential Impact includes a 2.25 km buffer extended out on all sides from the FR and GMA boundaries, except for the uphill (mauka) boundary along the Pōhakuloa Training Area (PTA) border where a boundary fence limits ungulate ingress (Figure 1.2). The buffer is based on half the maximum home range width. Because the game management activities within the Plan Area support game mammals and the animals may potentially leave the Plan Area boundary, DOFAW is responsible for the impacts of those animals within the buffer outside the Plan Area.

Background information from the Management Plan (DLNR 2003) applies directly to the HCP, and is therefore repeated here (pages 1-5)⁵. In addition, the coverage area of the Management Plan does not extend into the mauka lands of Pu‘u Anahulu, and there is currently no

⁵ Note that the geographic setting and scope of activities in the Management Plan show some overlap but differ from than that of the current this HCP.

management plan in place for this area. In lieu of a management plan, the guiding principles of the Pu‘u Wa‘awa‘a Management Plan will be used wherever applicable. For more in depth background information, please refer to the PWWMP.

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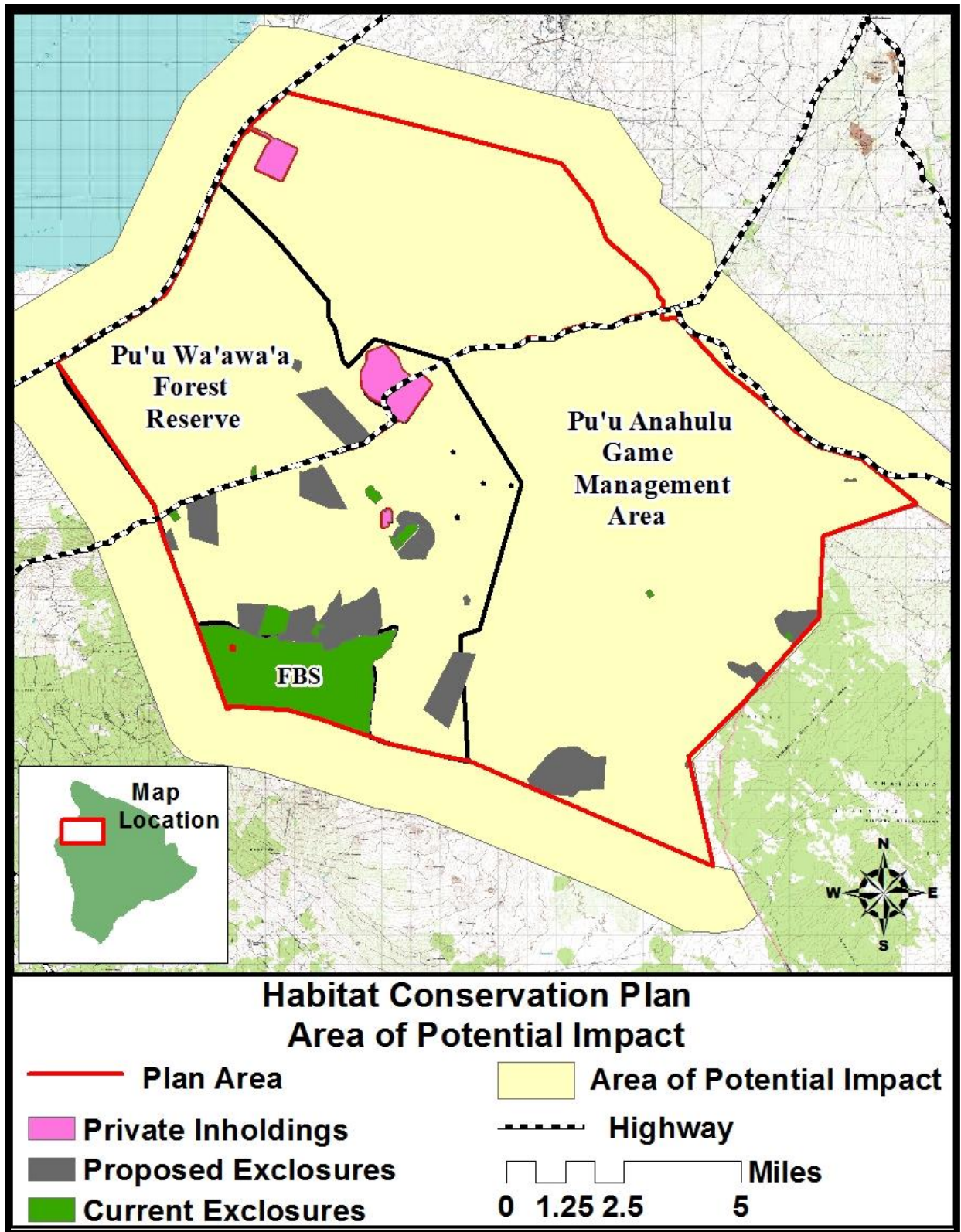


Figure 1.2 Area of Potential Impact (149,228 acres).

1.2.2 Purpose and Need for the Plan

Hawai‘i’s natural resources are managed under the authority and mandates of several laws and regulations. State law authorizes and mandates the protection, conservation, development, and utilization of wildlife resources of the State. Specifically, HRS §171-3 mandates that the Department of Land and Natural Resources (DLNR) shall manage and administer forests, forest reserves, wildlife, wildlife sanctuaries, game management areas, public hunting areas, Natural Area Reserves (NARs), and other functions assigned by law. HRS §183D-2 mandates that the Department shall manage and administer the wildlife and wildlife resources of the State which, by definition, includes both game and non-game species. §183D-3 further mandates that the Department shall adopt rules protecting, conserving, monitoring, propagating, and harvesting wildlife and under §183D-4, and that the Department is given the authority to maintain, manage, and operate game management areas, wildlife sanctuaries, and public hunting areas for these purposes. Within the DLNR, DOFAW has been delegated the management responsibility for terrestrial wildlife and the game management component of that program. It is because of this mandate that game mammal management occurs at Pu‘u Wa‘awa‘a and Pu‘u Anahulu. This HCP seeks to strike a balance between the needs of the game management program and the protection of the native biota found in the area.

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1.3 COVERED ACTIVITIES: Game and Fire Management in the Plan Area

1.3.1 Background

Hawai‘i’s game mammal management program provides public hunting opportunities across the state and Pu‘u Wa‘awa‘a FR and the Pu‘u Anahulu GMA (collectively the Plan Area) are popular hunting areas on the Island of Hawai‘i. Game mammals that are managed by the state in the Plan Area include feral pigs (*Sus scrofa*), mouflon sheep (*Ovis orientalis orientalis*), feral sheep (*Ovis aries*), and feral goats (*Capra hircus*). These animals, with the exception of mouflon sheep, were first introduced to Hawaii as a food resource, beginning with the Polynesian introduction of the feral pig. A 10 year ban on the slaughter of sheep and “other European animals” was set in 1794, to increase the stock. Mouflon were introduced to Hawaii in 1957 to improve the quality of the feral sheep (Tomich 1986). Today, these game mammals continue to be an excellent resource for food, in addition to providing opportunities for both recreational and subsistence hunting. The custom of recreational hunting has evolved in Hawai‘i over the last 150 years as native Hawaiians assimilated western hunting traditions. Although only two percent of the state’s residents obtain a hunting license, hunting is a visible and common occurrence across the state (Maly et al. 2013). However, game mammals in Hawai‘i are not native and have negative impacts on sensitive native species and ecosystems (Coblentz 1978, Miller and Travis 1996, Cabin et al. 2000, Campbell and Long 2009, Spear and Chown 2009, Nunez et al. 2010, Thaxton et al. 2010, Cole et al. 2012). Both PWWFR and PAHGMA contain a significant area of tropical dry forest (Giffin 2003), a globally endangered ecosystem (Miles et al. 2006, Thaxton et al. 2010) that contains many rare and endangered plant and animal species.

Native plants in Hawai‘i evolved in the absence of browsing and grazing mammals and they often lack physical and chemical defenses that would help to protect them (Stone, 1984). Within tropical dry and mixed-mesic ecosystems in Hawai‘i, the effects of non-native ungulates on the environment interact with other factors including drought, invasive plants (e.g. fountain and kikuyu grasses [*Pennisetum setaceum* and *P. clandestinum*]), wildfire, and anthropogenic disturbances (Allen 2000, Blackmore and Vitousek 2000, Cabin et al. 2000, Cabin et al. 2002, Elmore and Asner 2006, Castillo et al. 2007, Cordell and Sandquist 2008, Brooks et al. 2009, Thaxton et al. 2010). In particular, large-scale wildfires have eliminated large portions of dryland forest in Hawai‘i due to the buildup of alien grass biomass, creating a persistent grass-wildfire cycle (Hughes et al. 1991, D’Antonio and Vitousek 1992, Hughes and Vitousek 1993, D’Antonio et al. 2011). This *grass—fire cycle*, where ecosystems that are heavily invaded by alien grasses are more likely to burn, and consequently are more likely to be further invaded by alien grasses, can limit the re-establishment of natives (Hughes and Vitousek 1993). Furthermore, conversion of forests to grasslands due to fire can degrade and reduce habitat quality for game mammals. The result of these combined factors is habitat alteration and loss for Hawai‘i’s native flora and fauna and consequent decline in populations and loss of native species. Wildfire has been identified as a priority threat to the Plan Area, and fire management is critical if natural resource management and game management are to continue. Below is a description of the game mammals present in the Plan Area, a history of their introduction to Hawaii, and a summary of game management in the Plan Area. Following this background information are the specific Covered Activities for game and fire management for this HCP.

1.3.1.1 Feral Pigs (*Sus scrofa*)

Pigs were the first ungulates (hooved mammals) introduced to the Central Pacific Islands by the earliest colonists to Hawai‘i over 1000 years ago (Kirch 1982, Hess and Jacobi 2011). In 1793, other pig varieties, notably the European boar, were introduced to Hawai‘i and presumably hybridized with the Pacific variety (Tomich 1969, Ziegler 2002, Nogueira-Filho et al. 2009). Today, feral pigs are abundant in Hawai‘i’s tropical forests. Pigs disturb soil by rooting for invertebrates, especially non-native earthworms (Environment 2015), and they can act as vectors for the spread of invasive plant species such as banana poka (*Passiflora tarminiana*) and strawberry guava (*Psidium cattleianum*), (Diong 1982, Nogueira-Filho et al. 2009). Notably, disturbances by pigs create breeding grounds for mosquitoes which spread diseases among birds such as avian malaria and avian pox (LaPointe 2006). Feral pigs are most abundant in the more mesic areas of Pu‘u Wa‘awa‘a (above 1,067 m elevation), though they do occur as low as 762 m in elevation.

1.3.1.2 Feral Sheep (*Ovis aries*)

Sheep were initially introduced to the island of Hawai‘i by Captain George Vancouver in 1793 (Hess and Banko 2011). Because of a lack of predators, feral sheep populations have increased dramatically in Hawai‘i since their introduction. Feral sheep are often considered grazers, preferentially consuming grass, but they can also browse woody vegetation such as māmane (*Sophora chrysophylla*) (Scowcroft and Giffin 1983). Feral sheep can cause soil erosion and degradation when herds occur in high densities on steep slopes. On Mauna Kea, damage to native vegetation due to grazing and browsing by feral sheep has been cited as one of the causes for the inclusion of 15 Hawaiian plant species in the list of threatened and endangered species in the U.S. (Ripley 1974, Scowcroft and Giffin 1983, ISSG 2010). In the Plan Area, aerial surveys conducted by DOFAW have documented that feral sheep are widespread in many areas, especially near the Pu‘u Lani Ranch subdivision in Pu‘u Anahulu. A study of sheep movement patterns (2002-2005) in the Plan Area showed that sheep generally used well-defined ranges, characterized by repeated movements back and forth across their established ranges. There were no instances of clear dispersal from one area to another. Sheep were found more frequently in open areas during the morning and late afternoon periods, feeding in small herds. On cloudy days, sheep tended to remain in more open areas for longer periods. During the hottest portion of the day sheep were often found bedded down beneath the shade of trees or shrubs. The calculated home ranges for sheep in the Plan Area are 9.35 km² for ewes and 12 km² for rams. See appendix A for a detailed description of this study.

1.3.1.3 Feral Goats (*Capra hircus*)

Feral goats were likely first introduced to the island of Hawai‘i by Captain James Cook in 1778 (Stone & Anderson 1988). They are currently present from sea level to higher elevations on all of the main Hawaiian Islands with the exception of Lāna‘i and Kaho‘olawe where they were successfully eradicated in 1981 and 1990 respectively (Hess and Jacobi 2011). Feral goats are mainly considered browsers, consuming the vegetation of woody plants, but they also consume graminoids (*grasses, sedges, and rushes*) (Williams 1980). By preferentially browsing on palatable tree species, goats limit or prevent the replacement of adult trees that form a native canopy (Scowcroft and Giffin 1983, Stone and Anderson 1988, Hess and Jacobi 2011)(Stone & Anderson, 1988). For example, by 1900 on the island of Lāna‘i, large areas of the island were deforested due to the activities of sheep and goats that were introduced in the mid-1800s (Hess

and Jacobi 2011). Historically at Pu‘u Wa‘awa‘a Ranch, large goat drives were conducted by early ranchers where goats were pushed to lower elevations at Kīholo Bay and dispatched (Maly and Maly 2006, Springer 2012). In the Plan Area, aerial and roadside surveys conducted by DOFAW show that most of the goat populations occur below Māmalahoa Highway surrounding the Hawai‘i Island Country Club in Pu‘u Anahulu, though other populations exist near Pu‘u Wa‘awa‘a itself and along the Māmalahoa Highway. The calculated home ranges for for goats in the Plan Area was 16.3 km² (See Appedix A, section 8.0).

1.3.1.4 Research on Game Population Abundance

Knowing the abundance of game species in the Plan Area is critical for making management decisions regarding harvest limits and acceptable impacts on habitat. Game mammal abundance for feral sheep, goats, and pigs will be estimated by DOFAW staff using aerial surveys in the Plan Area. Flight transects will be established and will be flown repeatedly, and flight time, belt-transect length, search time and protocol, and weather will be standardized as much as possible so that repeated surveys will provide information on relative abundance. Relative abundance estimates will provide an index of changing ungulate abundance over time that can be correlated with environmental variables and habitat impacts. However, more research on foraging, seasonal patterns and movements, and habitat use will improve future management decisions.

Conservation and research efforts in the Plan Area have benefited greatly from the establishment of the Hawai‘i Experimental Tropical Forest (HETF) Pu‘u Wa‘awa‘a Unit in 2006. The HETF was authorized by the Secretary of Agriculture in 1992 through passage of the Hawai‘i Tropical Forest Recovery Act (1992). Section 606 of the Hawai‘i Tropical Forest Recovery Act states that the HETF shall be managed as: (1) a model of quality tropical forest management where harvesting on a sustainable basis can be demonstrated in balance with natural resource conservation; (2) a site for research on tropical forestry, conservation biology, and natural resource management; and (3) a center for demonstration, education, training, and outreach on tropical forestry, conservation biology, and natural resources research and management. In 2006, the Hawai‘i DLNR Land Board approved a Cooperative Agreement between the USDA Forest Service and DLNR to manage the HETF, which include State Lands in Pu‘u Wa‘awa‘a. In 2007, DLNR granted a use permit to the USDA Forest Service for the HETF for purposes of research, education, demonstration, and related purposes. Currently, DOFAW and the USDA Forest Service work together to coordinate research, management, outreach, access, and education within HETF lands. Future collaboration on research within the HETF relating to game mammal management will inform game management activities in the Plan Area.

1.3.1.5 Habitat Management for Game Resources

To continue to provide public hunting opportunities in the Plan Area, areas outside of current and proposed exclosures are available for public hunting areas and are managed as a sustained yield resource. In this context, sustained yield of feral, non-native ungulates will be defined as maintaining sufficient game population abundance and productivity to provide on-going public hunting opportunities (DOFAW Management Guidelines 2001⁶). DOFAW will also take into account the needs of the hunting community when considering management actions in the Plan

⁶ The DOFAW Management Guidelines are being updated. Classification of management in the Plan Area may change based on the new guidelines.

Area. Management actions that enhance game population abundance (including but not limited to improving habitat quality, installation and maintenance of game guzzlers, and hunter quotas or bag limits) will be used to help facilitate an annual sustainable harvest.

Natural resource management objectives in this HCP mandate that game mammals be removed from inside fenced exclosures. Game mammals have been observed utilizing much of the habitat that is located within the proposed fenced exclosure areas, as these areas can contain relatively good game mammal habitat. It is likely that alternate habitat (habitat outside of proposed fenced areas) will need to be enhanced in order to provide game mammal hunting opportunities, and to ensure a quality hunting experience which can be quantified by hunter success rates. Additional research conducted by DOFAW, and through the Hawai'i Experimental Tropical Forest and other research activities in foraging behavior, seasonal patterns and movements, and habitat suitability will assist in managing these species across the landscape.

1.3.2 Covered Activity # 1: Hunting and Harvest

Portions of Pu'u Anahulu GMA and Pu'u Wa'awa'a FR are actively used by hunters for both game bird and game mammal hunting. Hunting is conducted by residents from all over Hawai'i for food, sport, recreation, and social interaction. Formal public hunting programs at Pu'u Wa'awa'a Ranch date back to 1978, although this activity has a much longer history in the area, likely dating to pre-contact times. Species subject to hunting include feral sheep, mouflon hybrid sheep, goat, pig, and game birds.

All public hunting is currently administered via either manned or unmanned hunter check stations and requires hunting licenses and additional harvest tags for selected game. Game bird hunting in both Pu'u Wa'awa'a Forest Reserve and Pu'u Anahulu Game Management Area is typically open during weekends and state holidays from November through January, and in March. Game mammal hunting in Pu'u Anahulu Game Management Area is typically open during weekends and state holidays from March to June. In Pu'u Wa'awa'a Forest Reserve, feral sheep and goats are currently harvested through the issuance of nuisance control permits. Historical trends in Pu'u Wa'awa'a Forest Reserve show a sharp increase in the harvest of goats since 2007 with a corresponding decrease in sheep and pig harvest, which reached their peak in 2000 (**Error! Reference source not found.**). These trends are driven by a combination of animal abundance and distribution, hunter preference and effort, and focal game species that are selected by wildlife officials, as well as bag limits.

Information from biannual aerial surveys will be used in part to determine acceptable harvest limits that lead to sustained populations of game mammals in the Plan Area. Adaptive management will be used to readjust harvest limits over time if necessary. For example, if sensitive areas are being affected by mammal activities, such as increased soil erosion, then nuisance control permits may be issued to reduce populations of game mammals. If public hunting does not adequately reduce ungulate abundance in these cases, then staff control will be used to help protect the resources.

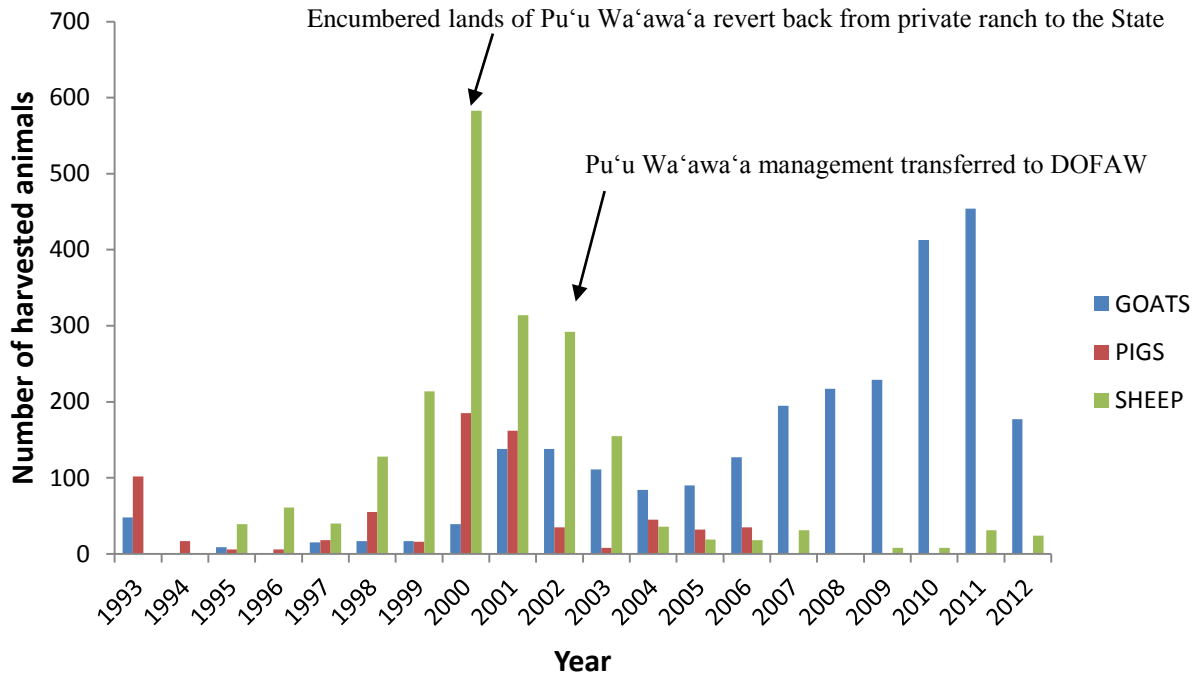


Figure 1.3 Historical trends in number of animals harvested (goat, sheep, and pig) from 1993 to 2012 at Pu'u Wa'awa'a Forest Reserve (includes both nuisance control permits and regular hunting).

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1.3.3 Covered Activity # 2: Habitat Enhancement for Game Mammals

Planting and protection of seedlings are necessary to recover portions of degraded forest that were lost to fire and non-native ungulates. To mitigate the previous loss of game mammal habitat, fast growing, non-fire prone, non-invasive herb, shrub, and tree seedlings (both native and Polynesian introduced) will be planted annually at multiple sites in the Plan Area that will be chosen by DOFAW staff. These areas may be temporarily fenced and when these plants reach an age and height that allows them to escape the most harmful effects of ungulate browsing, fences will be removed so that game animals may use these areas. Currently, two such sites, both less than an acre in size, in the PAHGMA, have been fenced and have been planted with Kukui (*Aleurites mollucanus*). To reduce fire threat, field crews will reduce fine fuel loads (e.g. fountain grass and kikuyu grass) around these enhancement areas and in nearby fire breaks through manual cutting and herbicide application. Habitat improvement through these techniques will provide cover, bedding sites, and foraging opportunities for game mammals. These habitat management strategies will not only improve habitat for existing populations of game species, but may also be used as a management tool to draw animals away from ecologically sensitive areas. For this reason, game habitat enhancement areas will not be placed within 2.25 km (See *Plan History section 1.2.1*) of current or proposed conservation exclosures.

1.3.3.1 Food Plots

Other common habitat management and game population management practices include the use of food plots (to provide supplemental food resources), prescribed burns (to enhance and promote the growth of grasses and other fire-adapted food resources), and mineral supplementation (to improve health and nutrient resources for game animals) (Yarrow and Yarrow 1999). These management techniques are used to enhance the habitat of game species to sustain healthy populations over the long term. Food plots are used to help compensate for reduced food availability during fluctuations in resource abundance, but these will not be a substitute for properly managed habitat. Food plots can also be used to concentrate game in certain areas. To date, no food plots have been used in the Plan Area for game management purposes. Future food plots will use non-invasive plant species that are already found on the island of Hawai'i. Typically, plant species that are chosen for these plots are annual legumes that have high protein content, such as clover (e.g. species from the Genus *Trifolium*). For example, recommendations for food plots for white-tailed deer (*Odocoileus virginianus*) in the Southeastern United States include 4 to 5 percent cover of wheat and clover (Yarrow and Yarrow 1999).

1.3.3.2 Mineral Supplementation

Mineral supplementation is often used to supplement the diet of game mammals in areas with nutrient deficient or depleted soils, which have nutrient-poor forage. Mineral supplementation is usually provided by placing mineral blocks in the vicinity of a water unit. The substrate age of much of the land within the Plan Area is between 2,000 – 15,000 years old (Sherrod et al. 2007), and thus soil development is limited and nutrient poor. Moreover, the dominant grass type is fountain grass (*Pennisetum setaceum*) across the landscape until ~2,100 m elevation which then transitions into kikuyu (*Pennisetum clandestinum*)-dominated grassland (Wagner et al. 1999). Fountain grass is neither highly palatable nor nutritious as a forage grass. It may be grazed intensively by sheep or cattle in early spring while shoots are tender and succulent. However, livestock will usually graze other desirable species first and avoid fountain grass when given a

preference (USDA 2012). Kikuyu grass, however, is relatively high in protein and is a preferred foraging grass species for game mammals and other wildlife (Black et al. 1994). Therefore, in areas dominated by fountain grass, occasional mineral supplementation may be necessary to maintain healthy game populations. Mineral supplementation can help with growth, development, and also provide critical nutrients for physiological maintenance of body functions, especially in those areas dominated by fountain grass.

1.3.4 Covered Activity # 3: Game Mammal Infrastructure

Other game management activities include the installation and maintenance of game guzzlers (watering troughs), and installation and maintenance of informational signage and hunter check stations. These actions are described in greater detail below.

1.3.4.1 Game Guzzlers and Cattle Troughs

Water is needed by game mammals for important physiological processes such as digestion, body temperature regulation, and waste elimination. However, the efficiency by which game mammals find and process water varies by species. Some species can obtain daily water requirements by eating plants or from dew on forage, and water can become available through the digestive process when it is a metabolic by-product of breaking down fat and starches. Precipitation in the Plan Area ranges from 27.9 inches of mean annual rainfall at the Waihou I rain shed area near the Forest Bird Sanctuary, to less than 10 inches on the northern borders along Ka‘ahumanu Highway (Giffin 2009, Giambelluca et al. 2013). Drought combined with nutrient poor forage causes game mammals to consume more vegetation to meet nutritional needs and water requirements.

There are currently 24 game guzzlers and 41 cattle troughs scattered across different elevations and habitat types within the Plan Area (**Error! Reference source not found.**), however not all the cattle troughs are functional at this time. Game guzzlers (see **Error! Reference source not found.**) are watering troughs connected to large water tanks that are fed by rain catchment systems (usually tin or plastic roofing with rain gutters that lead to water tanks). Pipes from the water tank lead to a small trough with a float valve so that water will be re-filled in the container as it is emptied. The float valve shuts off the water when the water reaches a certain level in the trough to prevent overflow. Similarly, cattle troughs are larger long narrow open tanks with a float valve to refill as it is emptied. For the purposes of this HCP both game guzzlers and troughs function as a water source for game animals. Game guzzlers will not be placed in areas with endangered plant species that are unprotected (i.e. unfenced), and they may also be used strategically to draw animals away from sensitive areas. No new guzzlers will be built until HCP implementation has begun. This will help ensure that added water resources don't increase population abundance of game mammals to a point at which they harm sensitive resources in areas that currently lack large exclosures. During the 25 year ITL permit duration, we anticipate a maximum of two new units installed annually, for a total of 50 new units. Finally, all game guzzlers located within proposed exclosures will be either relocated or fenced off to restrict access to feral ungulates, leaving them accessible to game birds only.



Figure 1.4 Game guzzler located in the PAHGMA. Float valve and trough in the foreground, connected to the catchment system pictured in the background.

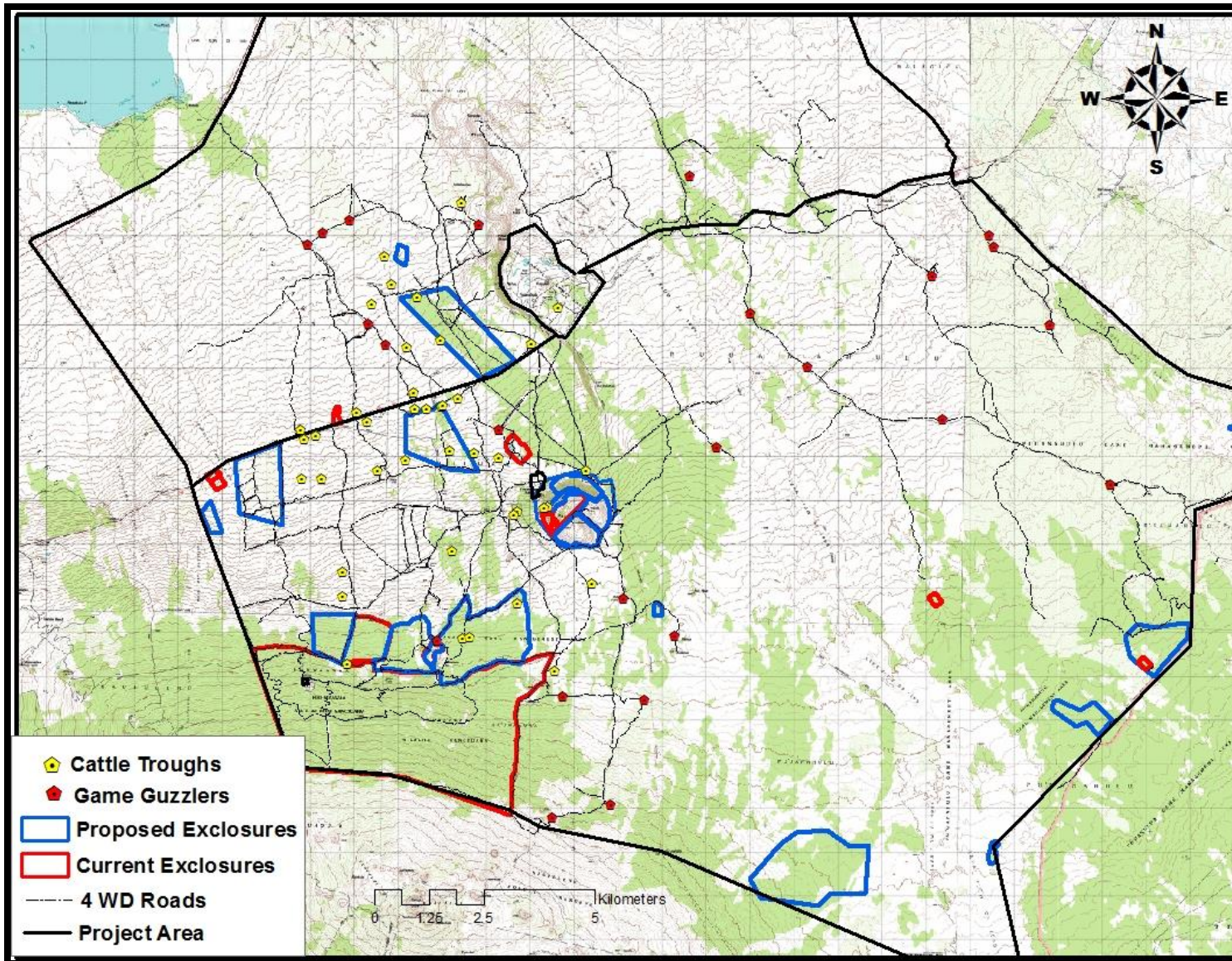


Figure 1.5 Game guzzler and cattle trough locations in the Plan Area. Not all cattle troughs are functional.

1.3.4.2 Information signage

To help facilitate smooth and efficient hunting activities for all parties involved, hunting boundaries, rules and guidelines, fire risk reduction protocols, and protected and sensitive areas that are closed to access must be known by hunters. In order to meet this objective, informational signage will be installed along hunting boundaries and in appropriate places along trails and roadsides (as well as at hunter check stations and hiking trail kiosks). A hunter check-station, located just inside the main entrance of Pu‘u Wa‘awa‘a, may be staffed during hunts.

1.3.5 Covered Activity # 4: Game Mammal Population Augmentation

Population augmentation using translocation and captive breeding has been a wildlife management tool for as long as humans have been humans (Seddon et al. 2012). To increase hunter opportunity in the Plan Area, populations of current ungulates species present (specifically mouflon and feral sheep and feral goats) will be supplemented and increased. Animals used for augmentation will be translocated from other extant populations on Hawai‘i Island. Augmentations will not occur until Phase I of HCP implementation is complete, and fences around avoidance and minimization and mitigation areas have been constructed. Temporary holding pens may be installed in non-exclosure locations to help translocated animals acclimate to the area.

1.3.6 Covered Activity # 5: Fire Management

Fire management is integral to both natural resource management as well game management and hunting in the Plan Area. The below activities (1.4.6.1 to 1.4.6.2) describe the primary forms of fire management used to reduce the likelihood of fire as well as facilitate rapid response when fires do occur. For a more detailed discussion of fire management in the North Kona region, please see Appendix H.

1.3.6.1 Maintenance of roads and fuel-breaks

Access to hunting areas in the Plan Area is gained through the use of 4 wheel-drive roads that also act as fuel breaks. Currently there are approximately 230 miles of roads and fuel breaks within the Plan Area. Fountain grass, tree tobacco, and other non-native species such as fireweed (*Senecio madagascarensis*) heavily colonize these roads creating hazardous fuel loads and elevated fire risk. Previous catastrophic fires in this area have been attributed to ignition from hot catalytic converters from vehicles parked on tall dead grass. To mitigate the threat of wildfire and allow hunting and management access, it is critical that roads be cleared of vegetation as needed through the use of chemical and mechanical removal methods. Specifically, road clearing consists of manually cutting weeds as well as spraying herbicides that are approved for use in forests (*Methods are described in the Impacts section 5.2.2*).

1.3.6.2 Cattle grazing to reduce fuel loads

Continuous grazing operations have existed in Pu‘u Wa‘awa‘a for over 100 years (Fujii 1995, DLNR 2003). Many within the homestead communities of Pu‘u Anahulu can trace their family history and livelihood to involvement with Pu‘u Wa‘awa‘a Ranch. Many of the older families in the community are direct descendants of former ranchers and ranch workers at Pu‘u Wa‘awa‘a. While grazing at Pu‘u Wa‘awa‘a and Pu‘u Anahulu has contributed to the decline of native ecosystems, it has become a practical tool for protecting existing remnant dryland ecosystems by mitigating the buildup of fine fuels. Fountain grass and kikuyu grass are widespread in the Plan

Area. Both grasses produce large amounts of highly flammable fuel. Approximately 90% of all wildfires started in this area can be attributed to roadside ignition, a condition that will continue if left unmitigated. Grazing is used as a tool to mitigate the frequency of wildfires within the PWWFR. Currently, leases for cattle grazing in Pu‘u Wa‘awa‘a are by special use permit, renewable annually. DOFAW is working with the Pu‘u Wa‘awa‘a Advisory Council to develop a grazing management plan to be released for public review in the near future. Once finalized, the grazing management plan should allow for longer term cattle grazing leases in the area. This Plan considers the effects of cattle in terms of take of Covered Species to be the same as that of game mammals in the Plan Area.

1.3.6.3 Prescribed burning for fuels management

Prescribed burning may be used in the future as a tool to reduce fuel loads and enhance game bird and mammal habitat in Puu Anahulu GMA. Prescribed burning would only be used in highly degraded areas to avoid any impact to Covered Species in the Plan Area. Burning fountain grass and other non-native plants reduces the amount of fuels thereby limiting the risk of wildland fires. Additionally, prescribed burns can stimulate new growth that provides forage for game animals. An Environmental Assessment (EA) would need to be completed and new fire breaks constructed before prescribed burning can be used as a tool for fire management and game habitat enhancement.

2.0 DESCRIPTION OF THE HCP

2.1 PURPOSE AND NEED FOR THE HCP

This HCP has been prepared to meet the requirements of HRS Chapter §195D, which apply to the management of game and maintenance activities associated with the proposed Plan. An HCP is needed because game mammal management activities have the potential to result in take of endangered and threatened species that inhabit or utilize the Plan Area, including: Blackburn's sphinx moth and 15 plant species. Under HRS §195D-4(g), DLNR will authorize take through the issuance of an ITL. An HCP must be prepared in support of the application for a state ITL. The HCP establishes the measures and means required to meet the conservation needs of endangered and threatened species in the Plan Area, while at the same time preserving the DLNR's ability to pursue its game management objectives with assurances that incidental take of Covered Species is authorized.

The purposes of the HCP are to: 1) describe the geographical area encompassed by the plan; including the ecosystems, natural communities, or habitat types and the endangered species that occur therein; 2) determine the potential impacts that game mammal management may have on the listed species or species under consideration for listing; 3) ensure that the impacts of the take will, to the maximum extent practicable, be minimized and mitigated; 4) provide a schedule for implementation; 5) ensure that adequate funding for the HCP will be provided; 6) provide reasonable certainty the ecosystems, natural communities, or habitat types will be maintained in the plan area, throughout the life of the plan, in sufficient quality, distribution, and extent to support the species covered under the HCP; and 7) implementation of the HCP will provide a net benefit to the Covered Species.

The need for the HCP is to authorize, pursuant to HRS Chapter §195D, the take of state-listed threatened or endangered species (or species under consideration for listing) incidental to the management activities of the Plan. In order to obtain such authorization, the DLNR developed an HCP that meets issuance criteria for an ITL. The HCP assists DLNR with regulatory compliance under HRS Chapter §195D, serving as a vehicle for obtaining regulatory stability and predictability.

2.2 SCOPE AND TERM

This HCP seeks to offset the potential impact of the proposed game mammal management activities on the listed species (i.e. Covered Species) with measures that protect and provide a net benefit to these species island-wide and statewide. The Applicant anticipates a 25-year Plan life, throughout which this HCP would be in effect. With monitoring and review by the ESRC (Endangered Species Recovery Committee) and DLNR, the provisions for adaptive management will allow mitigation of Plan impacts to be adjusted appropriately. Accordingly, this HCP includes provisions for monitoring and adaptive management to allow flexibility and responsiveness to new information over the life of the Plan. Monitoring and adaptive management will be coordinated within DLNR.

2.2.1 List of Preparers

This HCP was prepared by State of Hawai'i, Department of Land and Natural Resources, Division of Forestry and Wildlife.

2.3 SCHEDULE

Implementation of this HCP will be done in three phases. Phase 1: Avoidance and Minimization Phase, years 0-8, Phase 2: Mitigation Phase, years 5-15, and Phase 3: Maintenance, years 16-25. There is considerable overlap between fencing enclosures that are used for avoidance and minimization, and mitigation. In most cases, these fenced conservation units provide avoidance of take for a given species while also allowing for mitigation sites for additional Covered Species. In these cases, avoidance/minimization and mitigation activities may occur concurrently. What follows is a general description of activities within each phase of implementation. Management and monitoring activities are described in further detail in the monitoring section of this HCP (*See section 7.2*).

The PWWMP is currently being implemented in the Pu‘u Wa‘awa‘a section of the Plan Area, and the activities and goals of this HCP overlap considerably. The actions taken through the PWWMP will work towards fulfilling avoidance and minimization, and mitigation goals required for this HCP. Current management activities include fuelbreak maintenance, outplanting, weed control, seed collection, fencing individual Covered plant species, establishing new fenced units, and removal of ungulates from established fenced areas.

Phase 1: 0-8 years: Avoidance and Minimization:

- Install Avoidance and Minimization fence enclosures (protection of *in situ*, or naturally occurring wild individuals of Covered Species).
- Initiate enclosure management, once fences are installed, including:
 - Remove ungulates.⁷
 - Reduce overall alien plant cover: remove 90% of fountain grass and kikuyu grass⁸ from within 3 meters of an individual (or cluster of) Covered Species and, maintain a 25-50 m buffer of less than 50% invasive grass coverage around an individual (or cluster of) Covered Species.
 - Conduct rodent and slug control, or other threats (as necessary).
 - Maintain fuelbreaks around fence lines.
 - Conduct quarterly fence line and ungulate ingress checks.
- Full census of each Covered Species within a given enclosure (within a year of installation) to re-establish baseline and add any losses to mitigation goal.

⁷ Upon the completion of fence construction, ungulates will be removed following ungulate control methods as outlined in State of Hawai‘i Technical Report No. 07-01, *Review of Methods and Approach for Control of Non-native Ungulates in Hawai‘i* (DLNR 2007). Ungulate removal will depend on size and location of the enclosure and will include public hunting, animal drives, and if necessary, staff removal.

⁸ Fountain (*Pennisetum setaceum*) and kikuyu (*Pennisetum clandestinum*) grass have been identified as the most damaging invasive plant species in the Plan Area. Additional weed species will be controlled on a case by case basis. Some alien species, such as kikuyu grass can hinder the encroachment of more aggressive weed species allowing for better outplanting conditions and can be left in place until outplants are near ready to be planted.

- Begin using these exclosures to mitigate for additional appropriate Covered Species not currently occurring within the exclosures.
- An avoidance/minimization and mitigation monitoring plan will be developed within three years of Plan approval.
- Begin annual monitoring of *in situ* populations.
- An invasive species quarantine and response protocol will be developed within three years of Plan approval.

Phase 2: 5-15 years: Mitigation:

- Install remaining Mitigation fence exclosures.
- Initiate exclosure management:
 - Remove ungulates.⁹
 - Reduce overall alien plant cover.
 - Outplant to mitigation goal (+ expected % mortality) in appropriate exclosure for each Covered Species.
 - Conduct rodent and slug control, and other threats (as necessary).
 - Maintain fuelbreaks around fence lines.
 - Conduct quarterly fence line and ungulate ingress checks.
- Initiate mitigation outplanting and monitoring.
- Plant non-listed native species to provide net benefit to the ecosystem.

Phase 3: 16-25 years: Maintenance:

- Continue monitoring *ex situ* and mitigation populations.
- Initiate adaptive management based on monitoring results.
- Replant Covered Species to meet mitigation goals.
- Plant non-listed native species to provide net benefit to the ecosystem.

⁹ Upon the completion of fence construction, ungulates will be removed following ungulate control methods as outlined in State of Hawai'i Technical Report No. 07-01, *Review of Methods and Approach for Control of Non-native Ungulates in Hawai'i* (DLNR 2007). Ungulate removal will depend on size and location of the exclosure and will include public hunting, animal drives, and if necessary, staff removal.

3.0 ENVIRONMENTAL SETTING

3.1 GEOLOGY

The Island of Hawai‘i is relatively young on a geological time scale. Geologists estimate that the oldest lava flows are less than 500,000 years old (McDougall and Swanson 1972). Hualālai, an active shield volcano, is the third oldest (130,000 years old) of the five volcanoes on the Island (Moore and Clague 1992). The summit caldera is buried, but the mountain rises to a height of 8,271 ft above sea level. Three major rift zones radiate from the top of Hualālai. One of these, a poorly defined northern rift, extends through the Kalamalu area of Pu‘u Wa‘awa‘a, and is about 10 km long and 5 km wide. Lavas of Hualālai are primarily Holocene in age, but some deposits date to late Pleistocene (Moore and Clague 1992). The last eruption of Hualālai occurred in 1801 creating the Huehue lava flow. Another eruption is highly probable in the next 200 years, but could occur in the next few decades (Moore et al. 1987). Walker (1990) considered Hualālai as potentially the most dangerous Hawaiian volcano.

Seismic activity within Hualālai is currently low and there is no evidence of magmatic movement such as occurs on Kīlauea and Mauna Loa (Clague and Dalrymple 1987). The last major earthquake at Pu‘u Wa‘awa‘a occurred in 1929. This event consisted of several thousand tremors that came from a source beneath Hualālai (MacDonald and Abbott 1970). The quake was especially severe at Pu‘u Wa‘awa‘a. Several ranch buildings were moved from their foundations and rock walls collapsed.

Hualālai's surface lavas are primarily alkalic olivine basalts. Tholeiitic basalts have been found offshore and in onshore drill holes (Walker 1990). The volcano is virtually un-dissected, but a few intermittent streams are subject to flash flooding. Erosion will probably not have a pronounced effect on the mountain for a long time, possibly for tens of thousands of years (Peterson and Moore 1987).

Two historic lava flows occur within the Pu‘u Wa‘awa‘a region. They are the 1859 flow from Mauna Loa and the 1800-1801 Ka‘ūpūlehu flow from Hualālai. Lava from these flows covered thousands of acres of native forest and was responsible for the destruction of several coastal Hawaiian villages and fish ponds. Both flows are poorly vegetated and only slightly weathered. Most substrates that are between these two historic flows originated from Hualālai. These vary greatly in age and intermingle to form a mosaic pattern in the lava bed (Giffin 2003).

3.1.1 Cinder Cones

An extinct volcanic vent known as Pu‘u Wa‘awa‘a cone and its associated 900-ft-thick lava flow (Pu‘u Anahulu ridge) are the oldest geologic formations on Hualālai (100,000 + years old). This distinctive hill is over one mile in diameter and rises 372 m above the surrounding landscape to a height of 1,209 m elevation. Erosion, following a radial drainage pattern, has cut many gullies and ridges on the cone's slopes. This geologically unique landform is composed of trachyte pumice and contains scattered blocks of trachyte obsidian or black volcanic glass. Trachyte is one of the most silicic lavas known in Hawai‘i. Due to its older age, high degree of soil development, and complex topography, Pu‘u Wa‘awa‘a cone has greater botanical diversity and supports a different plant community than the surrounding area.

Vegetation on the cone can be classified as an Olopua (*Nestegis*) montane forest (Wagner et al. 1999). At least 21 species of native trees have been reported from this rare mesic natural

community. Some like the Mānele or soapberry (*Sapindus saponaria*) are found nowhere else in the region. Several other prominent cinder cones occur at Pu‘u Wa‘awa‘a. These include Potato Hill, Pu‘u Iki, Po‘ohoho‘o and Kileo cones. Po‘ohoho‘o’s dual craters were excavated and fitted with rubber liners to store water for ranch use in the mid 1900’s. An asphalt catchment system collects water for the reservoirs (Juvik and Tango 2003). Many more small volcanic vents and cinder cones are scattered throughout the area, but most are unnamed (Giffin 2003).

3.2 SOILS

The most recent comprehensive soil survey of the Island of Hawai‘i (USDA 1973) shows several different soil types at Pu‘u Wa‘awa‘a. Recent field surveys indicate that the deepest soils at Pu‘u Wa‘awa‘a are the Wa‘awa‘a series that occur on Pu‘u Wa‘awa‘a cinder cone. They are almost 2 meters deep (Giffin 2003).

The ages of Hualālai lava flows have been summarized using correlations between soil depth and age (Moore and Clague 1992). Little or no soil cover (except in wet forest areas) occurs on lavas less than 5,000 years old. On lavas between 5,000-10,000 years old there is 10-20 cm of soil. Flows over 10,000 years old accumulate soils more than 20 cm deep.

3.3 CLIMATE

The weather pattern at Pu‘u Wa‘awa‘a is similar to that found along the Kona coast. Mornings are generally clear and sunny. During the day, the surface of Hualālai absorbs large amounts of solar radiation. This heats air over the mountain and creates updrafts. This rising air mass draws in moist marine air that condenses as it moves upward. The result is afternoon cloud cover and/or rain. The cycle reverses in the evening. Cold air descends from the mountain summit and drives cloud cover out to sea. Mean monthly temperatures measured at Halepiula rain shed were highest in September (71.6° F) and lowest in February (41.7° F). Winter frost sometimes occurs at upper elevations (Giffin, 2003).

Northeasterly trade winds have little influence on Pu‘u Wa‘awa‘a because of its leeward location in respect to other large mountains. Winds are generally light, but increase slightly during the winter months. Strong frontal storms may pass through the area once or twice a year and winds can reach hurricane force. These storms often uproot large trees or break trunks and limbs. Volcanic smog or "vog", released by Kīlauea Volcano, is often blown to west Hawai‘i by the trade winds and trapped there under an inversion layer. This haze consists of sulfur dioxide, ammonium sulfate, and ammonium hydrogen sulfate. On windless days, this natural pollutant sometimes drifts in from Kona and blankets Pu‘u Wa‘awa‘a. Vog usually persists until winds shift and cause it to be blown out to sea. Recent increases in volcanic activity, beginning in March 2008, have resulted in an increase of vog (SO₂ emissions) in the Kona region. A study by Nelson and Sewake has shown that vog can negatively impact a number of native and introduced plant species with symptoms ranging from leaf yellowing and bleaching to plant death (2008). The study also suggests seed germination may be affected. At this time, it is unknown if the flora occurring in the Plan Area is being negatively impacted by increased SO₂ levels.

3.4 HYDROLOGY

Infiltration of rainwater, fog drip, and dew are the primary fresh water inputs in the Pu‘u Wa‘awa‘a and Pu‘u Anahulu Ahupua‘a. Rainfall in the Project Area varies by topography and elevation. In general the southwest corner of the Project Area, the Forest Bird Sanctuary, receives the most rainfall. Precipitation gradually decreases when moving northeast as the elevation decreases. Precipitation in the Project Area ranges from 27.9 inches of mean annual rainfall at the Waihou I rain shed area near the Forest Bird Sanctuary, to less than 10 inches on the northern borders along Ka‘ahumanu Highway (Giffin 2003, Giambelluca et al. 2013). Differences in precipitation occur with increasing elevation (Figure 3.1). The rainfall zone changes from mesic at mid elevations to xeric at the upper and lower boundaries. Evaporation is relatively high, with over 100 inches of annual pan evaporation in the driest portion of the Plan Area (Ekem and Chang 1985).

Due to the high permeability of the Mauna Loa and Hualālai basaltic lava flows, there are no perennial streams in the Project Area. Surface flow is minimal and generally restricted to short-duration flash events. Subsurface water movement down to the groundwater aquifers is the main form of water transmission (Giffin 2003). The Plan Area lies on two aquifer units, the Kīholo Aquifer System Area and the ‘Anaeho‘omalū Aquifer System Area. The Kīholo Aquifer is on the northeast rift zone of Hualālai with an estimated sustainable yield of 18 million gallons per day. The ‘Anaeho‘omalū Aquifer System Area extends from the summit of Mauna Loa northwest to the western shores of ‘Anaeho‘omalū, and has an estimated sustainable yield at 30 million gallons per day (Lau and Mink 2006, Fukunaga 2010). Groundwater wells and rain water catchment systems are the two major sources of water supply in the area. Three man-made reservoirs are present and include two at Po‘ohoho‘o and one in the Hauaina enclosure (Giffin 2003). The Po‘ohoho‘o reservoirs are fed by rain catchment. The upper, smaller reservoir is partially functioning, and the lower, larger reservoir is non-functional. The reservoir at Hauaina is fed by rain as well as inputs from a well. There are three wells near or within the Plan Area. One is on Pu‘u Wa‘awa‘a Ranch property and one is in the Pu‘u Lani Subdivision. A third well, Old Kīholo well is no longer functioning, likely due to damage from an earthquake.

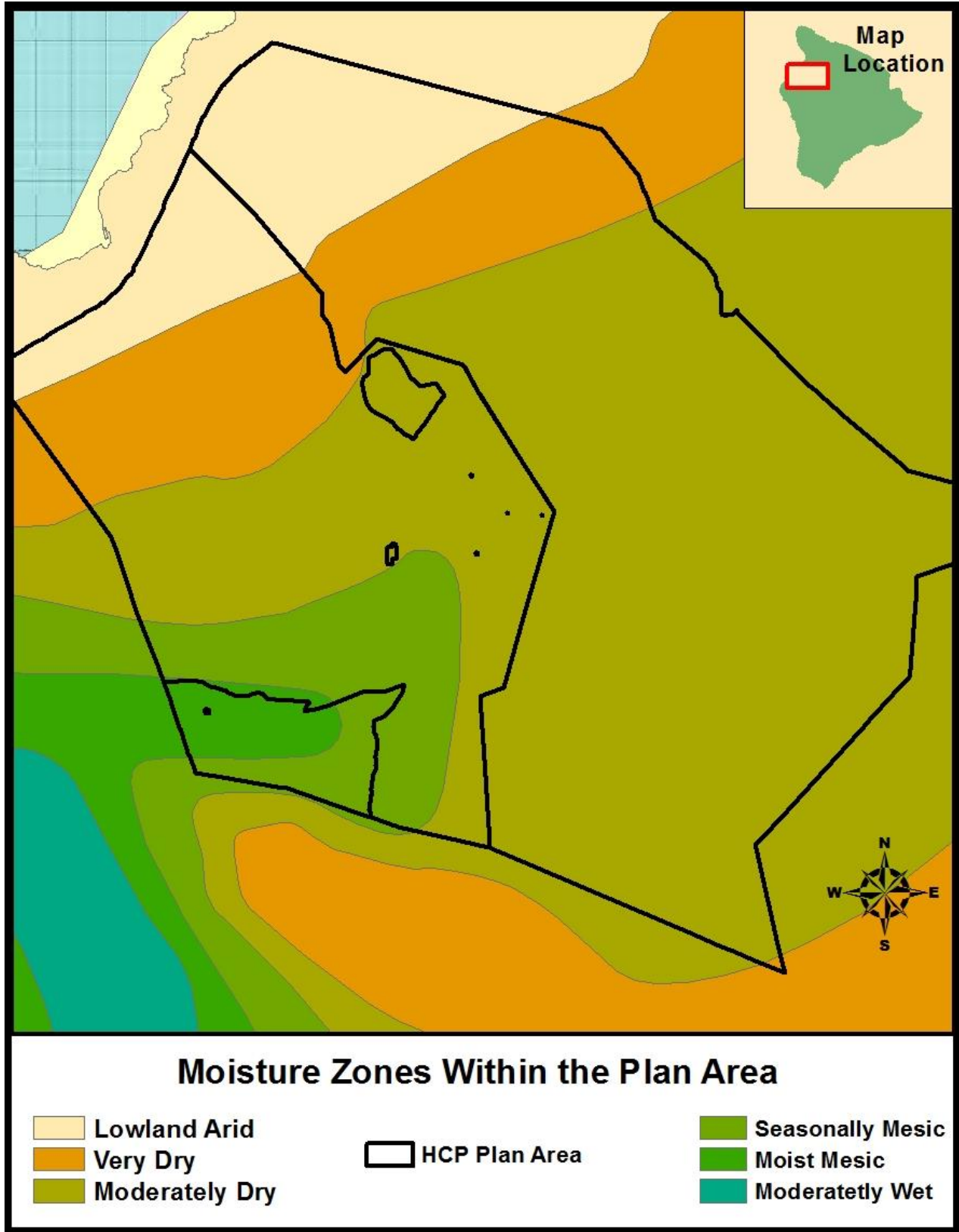


Figure 3.1 Moisture zones within the Plan Area.

3.5 FLORA

Covered Species likely to be impacted by Plan activities were identified through consideration of previous botanical surveys, on-the-ground botanical surveys performed as part of the HCP process, and previous biological assessments done in the area. The results of these surveys are included in this section. Following survey results, short descriptions of the species, their historic and current distribution, and habitat needs follow. Plants known to currently and historically occur within the Plan Area are listed in Appendix B. The areas encompassed by the Plan Area represent a highly diverse array of habitat types, ranging from dry shrublands and forest, to mesic-wet forest and subalpine shrubland. The dry forests of Hawai‘i were once host to some of the world’s most unique and diverse flora, and were richer in tree diversity than comparable areas of wet forest (Rock 1913, Carlquist 1980, Sohmer and Gustafson 1987). Dry forest ecosystems have experienced a rapid and significant loss of area throughout the world (Murphy and Lugo 1986, Janzen 1988, Bullock et al. 1995), and in Hawai‘i, these communities have now been reduced to approximately 10% of their former extent (Mehrhoff 1988, Brueggemann 1996). Extensive impacts on and alterations of these Hawaiian ecosystems began with the agricultural and hunting practices of the early Polynesians, their use of fire for land clearing, and the introduction of non-native animals such as the Polynesian rat (*Rattus exulans*) (Kirch 1982, Sadler 1999, Burney et al. 2001, Athens et al. 2002). This deterioration and loss accelerated after the arrival of Europeans through the introduction of ungulates such as cattle, sheep, pigs, and goats; further land clearing for agriculture and development, accidental and intentional fires, and the introduction of aggressive weeds including fire-carrying grasses such as fountain grass (Stone 1989, Cuddihy and Stone 1990, Loope 1998). The North Kona region of the island of Hawai‘i contains some of the largest remaining dry forest remnants in Hawai‘i (Giffin, 2003).

3.5.1 Vegetation Zones

Several different ecological regions are present at Pu‘u Wa‘awa‘a and Pu‘u Anahulu. Starting on the upper slopes of Hualālai and continuing downward, the following zones can be recognized: subalpine (generally above 1,828 m), montane (762-1,828 m), lowland (below 762 m) and coastal (sea level). A variety of vegetation communities occur within each zone. At mid elevations, montane dry woodlands dominate the eastern side of Pu‘u Wa‘awa‘a while moister montane mesic forests lie to the west.

Rare plants are found in all vegetation zones at Pu‘u Wa‘awa‘a and Pu‘u Anahulu. At least 46 rare plant taxa are historically known from the area to. Of these, 34 are officially listed as endangered or are proposed endangered species (Giffin, 2003), 17 of these species were found during HCP surveys. Botanical surveys reveal that a great number of plants have been extirpated at Pu‘u Wa‘awa‘a in recent years. These include the endangered and threatened *Bonamia menziesii*, *Asplenium dielerectum*, *Gardenia brighamii*, *Ochrosia kilaueaensis*, *Dissochondrus biflorus*, *Mariscus fauriei*, and *Nesoluma polynesianum*. Many of these species still exist on adjacent lands, particularly at Ka‘ūpūlehu. Some rare plants, such as *Asplenium peruvianum* var. *insulare*, have only been found in lava tube openings where they are protected from ungulate damage.

Subalpine Zone

This zone is found at upper elevations on Hualālai and other high volcanoes in Hawai‘i. Plants growing here are adapted to relatively dry conditions and dramatic temperature fluctuations.

Days are typically hot and nights cold. These forests at Pu‘u Wa‘awa‘a are characterized by open, low stature ‘Ōhi‘a trees (*Metrosideros polymorpha*) and scattered stands of native shrubs and grasses. Dominant understory species are Pūkiawe (*Leptecophylla tameiameia*), ‘Ōhelo (*Vaccinium spp.*), ‘A‘ali‘i (*Dodonaea viscosa*), and various sedges and rushes. Native mints, lilies, and ferns often grow abundantly in shaded areas like lava tube openings.

Montane Dry Forest Zone

This zone is found directly below the subalpine zone on the eastern side of Pu‘u Wa‘awa‘a. Many rare and endangered plant species are found in this habitat type. Vegetation damage by feral ungulates, particularly goats and sheep, is widespread. These forests are dominated by ‘Ōhi‘a, Naio, and ‘A‘ali‘i. Scattered stands of Māmane, ‘Iliahi (*Santalum paniculatum*), and ‘Akoko (*Chamaesyce olowaluana*) are also present. Non-native grasses, such as fountain grass (*Pennisetum setaceum*) and weeds, such as fire weed (*Senecio madagascariensis*) have replaced most native understory species. Covered plant species that occur in the montane dry forest are *Asplenium peruvianum* var. *insulare*, *Stenogyne angustifolia*, Hawaiian Catchfly, and A‘e (*Zanthoxylum hawaiiense*). *Eragrostis deflexa*, a native grass and Species of Concern (SOC), is scattered throughout the Plan Area above 1,219 m elevation.

Montane Mesic Forest Zone

This zone is relatively moist, but not as wet as rain forests. The mesic forest supports a rich assemblage of vascular plant species. It is best represented in the Forest Bird Sanctuary. Koa (*Acacia koa*) and ‘Ōhi‘a are the dominant overstory tree species. Kōlea (*Myrsine lessertiana*) dominates the mid-story, while native short-stature trees and shrubs make up the understory. Introduced grasses, primarily Kikuyu (*Pennisetum clandestinum*), and native ferns, especially Laukahi (*Dryopteris spp.*), cover the ground in forest openings. Other ferns such as Hō‘i‘o (*Athyrium sandwichianum*), ‘Akolea (*Athyrium microphyllum*), and Palapalai (*Microlepia strigosa*) are common in wetter, shaded areas. No tree fern stratum exists although Hāpu‘u (*Cibotium glaucum*) is scattered throughout the forest.

Two species covered under this HCP, ‘Aiea (*Nothocestrum breviflorum*) and A‘e (*Zanthoxylum dipetalum* var. *tomentosum*), occur in the lower mesic zone. ‘Aiea is a stout tree in the nightshade family (Solanaceae). The montane mesic forest at Pu‘u Wa‘awa‘a changes from a Koa/‘Ōhi‘a community to an open-canopied ‘Ōhi‘a/ Māmane community at about 1,280 m elevation. This latter woodland is a transitional vegetation type that descends to about 914 m elevation. Although greatly altered, it is still an important conservation link between the moist montane and dry forest types.

The ‘Ōhi‘a/ Māmane woodland supports many rare and endemic plants and is still one of the most botanically diverse sections at Pu‘u Wa‘awa‘a. Trees that characterize this zone include Koa, ‘Akoko, ‘Iliahi, Kōpiko (*Psychotria hawaiiensis*), Pāpala (*Charpentiera obovata*), Pāpala kēpau (*Pisonia brunoniana*), Po‘ola (*Claoxylon sandwicense*), A‘ia‘i (*Streblus pendulinus*), Olopua (*Nestegis sandwicensis*), and Hō‘awa (*Pittosporum hosmeri*). The understory is composed primarily of non-native pasture grasses, but scattered stands of Kulu‘i (*Nototrichium sandwicense*), Mā‘ohi‘ohi (*Stenogyne rugosa*), and ferns (*Dryopteris*, *Pteris*, *Asplenium*) still persist.

Lowland Dry Forest Zone

This zone occurs below the montane forests. Lama (*Diospyros sandwicensis*) and ‘Ōhi‘a are the dominant tree species and occur in both mixed and pure stands. Other less common trees include Alahe‘e (*Psydrax odoratum*), Wiliwili (*Erythrina sandwicensis*), ‘Ohe makai (*Reynoldsia sandwicensis*), Hala pepe (*Chrysodracon hawaiiensis*), and Kauila (*Colubrina oppositifolia*). The relatively rare Lama and Lama/Kauila plant communities are restricted to this zone at Pu‘u Wa‘awa‘a. Descriptions of Pu‘u Wa‘awa‘a’s lowland dry forests and information on their floristic composition were presented in detail by Takeuchi (1991) and The Nature Conservancy (TNC 1992).

Endangered plants of the lowland dry forest are Ma‘o hau hele (*Hibiscus brackenridgei*), Uhiuhi (*Mezoneuron kaviense*), Koki‘o (*Kokia drynariodes*), Kauila, and Hala pepe (*Chrysodracon hawaiiensis*). Koai‘a (*Acacia koaia*) is a species of concern.

3.5.2 Previous Botanical Surveys in the Plan Area

Data were compiled from a number of sources documenting the locations of rare and endangered species found within Pu‘u Wa‘awa‘a and Pu‘u Anahulu. The data were then used to guide survey efforts in 2003-2007 for this Plan, in order to calculate baseline species numbers and locations, and to update and identify areas for conservation efforts within the Plan Area. The original data sources included in this review were:

- The Heritage Database (Hawai‘i Natural Heritage Program/Hawai‘i Biodiversity and Mapping Program): This survey maps the occurrences of listed species in Pu‘u Wa‘awa‘a and Pu‘u Anahulu. The primary source of these data is from botanical surveys conducted along DOFAW Forest Bird Survey transects in the early 1980s. The landscape has been greatly altered in the 30 years since these surveys and many of the individuals are no longer extant.
- Shaw, Castillo, and Close; Pu‘u Anahulu, (1997): This was a general botanical survey with an emphasis on threatened and endangered species. These data focused search efforts within Pu‘u Anahulu and upper Pu‘u Wa‘awa‘a during subsequent HCP surveys. In the years since this survey, frequent wildfires and the subsequent invasion of fountain grass (*Pennisetum setaceum*) have profoundly altered plant communities. Soil kīpuka located on the Keamuku flow, which were relatively free of fountain grass in 1997, are now overgrown by fountain grass. The result is a drastic reduction of available habitat for listed species. For example, Shaw et al. (1997) mapped the distribution of 12 individuals of *Melicope hawaiiensis* on the Keamuku flow. None of these individuals were found during subsequent HCP surveys and no recruitment of *Melicope hawaiiensis* has since been observed.
- Lyman Perry, Hawai‘i District Botanist (DOFAW), 1999-present: Rare plant locations mapped during periodic surveys within Pu‘u Anahulu and Pu‘u Wa‘awa‘a.
- Steve Evans (U.S. Army Pōhakuloa Training Area): This survey maps the locations of rare plants on adjacent Pōhakuloa Training Area (data property of U.S. Army and not included as appendix). This information guided survey efforts in the upper Pu‘u Anahulu region.
- Arnett survey, (2002): Survey of the recently-acquired Keamuku Parcel.

3.5.3 Plan Specific Botanical Surveys

3.5.3.1 2003-2007 Plant Surveys

Botanical surveys were conducted in the Plan Area from 2003 to 2007 to determine locations of rare and endangered species located within the Plan Area. The Plan Area is too large to survey completely; therefore a systematic sampling scheme was utilized. Survey areas were identified based on the following parameters: the likelihood of harboring listed species, mid-scale ecological conditions, predicted habitat parameters, as well as input from expert knowledge of the area. Previous survey maps, wildfire history, and lava flow substrate maps were used to select areas likely to harbor listed species. Consultations with Miles Nakahara (formerly Hawai‘i DOFAW), Lyman Perry, (DOFAW), Mick Castillo (Hawai‘i Natural Resource Services), and James Kwon (USFWS) also assisted in identification of these areas of high likelihood. These areas of potential habitat for listed species were then subject to systematic survey by a trained botanical survey crew.

Large portions of Pu‘u Anahulu and Pu‘u Wa‘awa‘a (particularly makai of Highway 190) have suffered repeated wildfires in the past two decades and prior (

Figure 3.2). The fires and subsequent fountain grass invasion have virtually eliminated native species from most of these areas. Plan survey efforts were therefore focused on remaining intact kīpuka in upper Pu‘u Anahulu and Pu‘u Wa‘awa‘a. In most cases, the surveyed areas have been spared from fires because the substrate is rough ‘a‘ā lava and does not yet support a blanket of fire-carrying fountain grass.

A large portion of the HCP surveys were carried out along systematic transects (Figure 3.3). Survey teams were comprised of two trained botanists who walked roughly parallel lines along each transect, navigating between waypoints with a hand-held Garmin 12 XL GPS unit. Transects were positioned 1 km apart oriented along the contour of the land in some cases, and mauka-makai in other cases, following waypoints every 500 m along transect pathways.

Using the Garmin GPS units, tracks were recorded at two minute time intervals, along all transects. Survey crews generally followed a straight transect, but could meander along transects in order to inspect nearby vegetation, and to search the area once a rare plant was located. In total, approximately 89.5 miles of transects were surveyed (Figure 3.3). Results from systematic transects were used in population estimate calculations.

The other survey method employed was “guided searching”, or sampling targeted areas with high likelihood for occurrence of rare plant species (Figure 3.3). Guided searches were conducted by two or more botanists searching in a “free form” manner in an area where a particular plant species of interest was likely to occur. Area selection for guided searches was based on elements such as past known locations, preferred substrate age and type, elevation, moisture level, and proximity to other known plant locations. GPS units were carried during guided searches and tracks were recorded at 2-minute time intervals (Figure 3.3). Successive guided searches were planned after reviewing the coverage and success of earlier search efforts.

Botanical surveys focused on endangered and threatened species. However, the location of locally rare species and SOC were also mapped. For all endangered and threatened species, the following data were recorded: date, time, UTM location, elevation, aspect, topography, slope, age, vigor, reproductive status, height, diameter at breast height (DBH), presence/absence of ungulate damage, substrate type, and habitat description (based on (Jacobi 2003)). For non-listed

locally rare species, the following data were recorded: number of individuals, UTM location, date, time, vigor, reproductive status, height, DBH, and notes.

Sixteen endangered plant species, totaling 2,242 individuals, as well as nine SOC totaling more than 9,000 individuals were identified and mapped during the 2003-2007 surveys (Table 3.1).

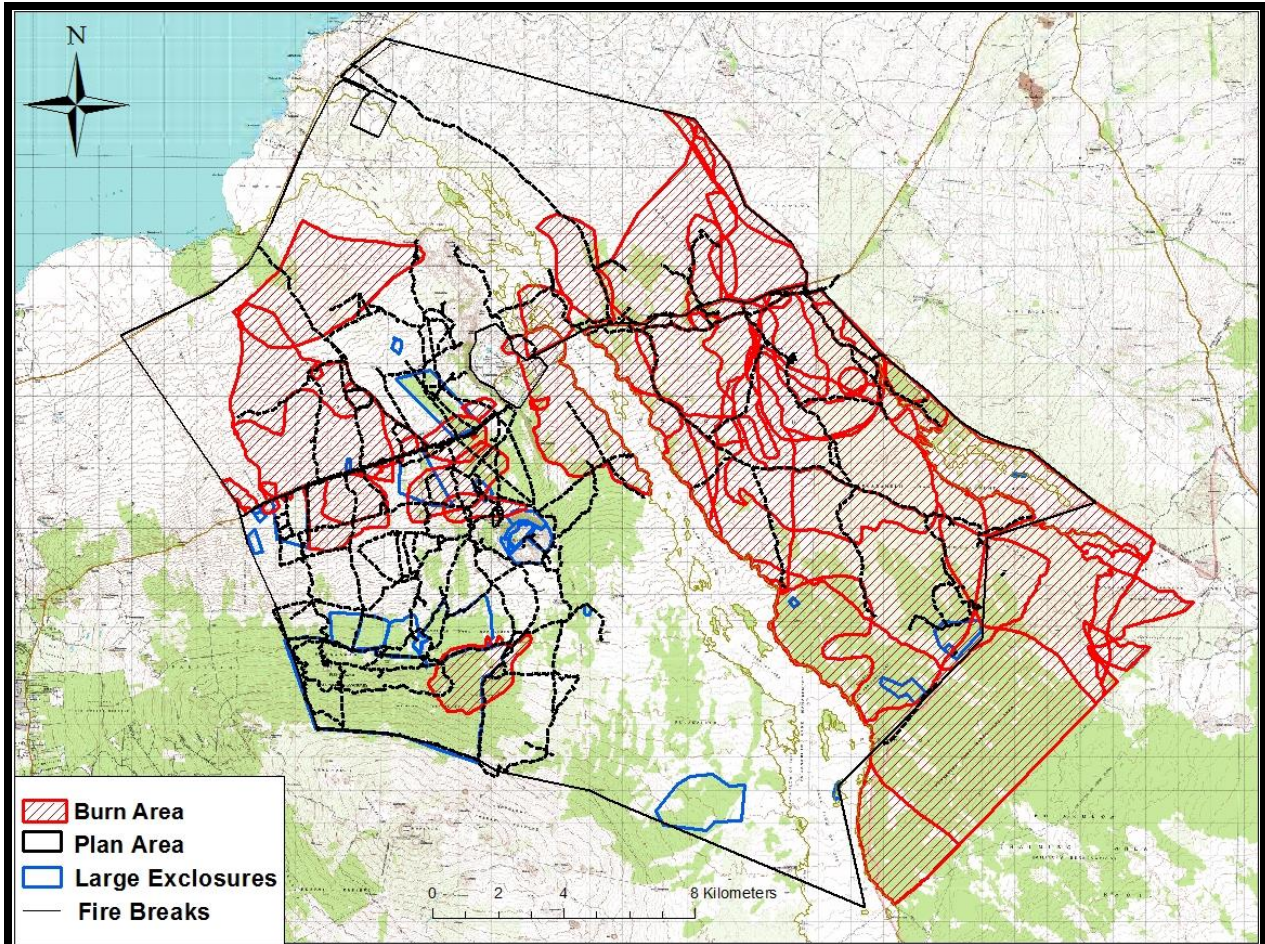


Figure 3.2 Locations of recorded fires that occurred within the Plan Area from 1975 to 2011.

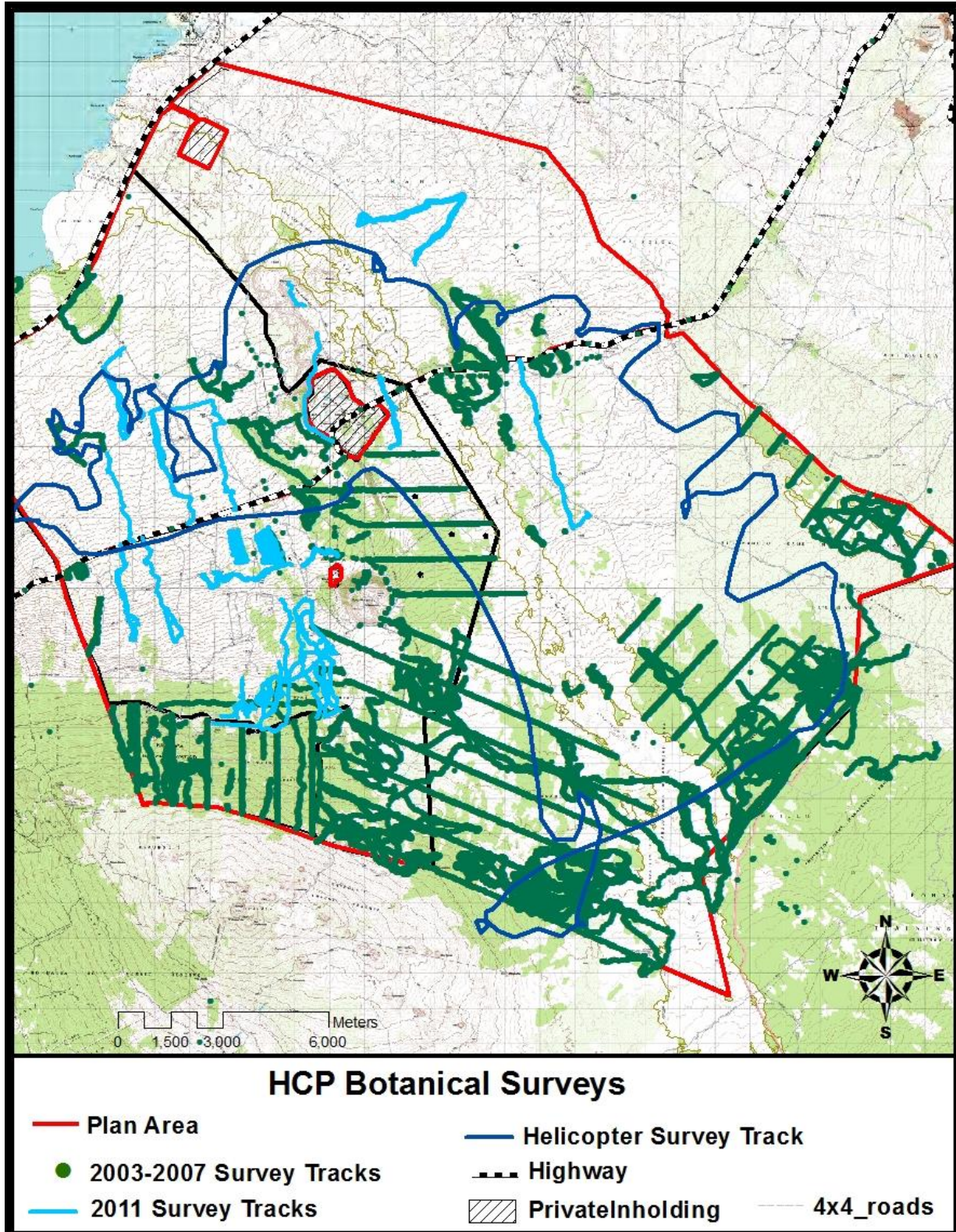


Figure 3.3 Ground (transects and guided searches) and aerial (helicopter) botanical survey tracks completed during the 2003-2007 and 2011 survey periods totaling 144 km of transects surveyed.

Table 3.1 List of species and number of individuals found during 2003-2007 botanical surveys.

Scientific Name	Common Name	# of Individuals
Endangered		
<i>Asplenium peruvianum</i>		64
<i>Chrysodracon hawaiiensis</i>	Hala pepe	334
<i>Colubrina oppositifolia</i>	Kauila	595
<i>Haplostachys haplostachya</i>	Honohono	80
<i>Hibiscus brackenridgei</i>	Ma‘o hau hele	65
<i>Kokia drynarioides</i>	Koki‘o	4
<i>Mezoneuron kawaiense</i>	Uhiuhi	48
<i>Neraudia ovata</i>		12 ¹⁰
<i>Nothoestrum breviflorum</i>	‘Aiea	151
<i>Phyllostegia velutina</i> ¹¹		35
<i>Silene lanceolata</i>	Hawaiian Catchfly	333 ¹²
<i>Solanum incompletum</i>	Pōpolo kū mai	14
<i>Stenogyne angustifolia</i>		98
<i>Vicia menziesii</i>		4
<i>Zanthoxylum dipetalum</i> var. <i>tomentosum</i>	A‘e	13
<i>Zanthoxylum hawaiiense</i>	A‘e	239 ¹³
Species of Concern		
<i>Alphitonia ponderosa</i>	Kauila	42
<i>Eragrostis deflexa</i>		732
<i>Euphorbia olowaluana</i>	‘Akoko	473
<i>Erythrina sandwicensis</i>	Wiliwili	11
<i>Exocarpus gaudichaudii</i>	Hulumoa	35
<i>Fragaria chiloensis</i>	‘Ōhelo papa	9
<i>Melicope hawaiiensis</i>	Alani	34
<i>Polyscias sandwicensis</i>	‘Ohe makai	21
<i>Sisyrinchium acre</i>	Mau‘u lā‘ili	64
<i>Stenogyne micrantha</i>		1
<i>Tetramalopium consanguineum</i>		8,000+
<i>Tetramalopium humile</i>		2

¹⁰ Three of these individuals occur on PTA lands.

¹¹ *Phyllostegia velutina* and *Vicia menziesii* are both located within the FBS where no game management occurs, and are therefore not Covered Species under this HCP.

¹² 98 of these individuals occur on PTA lands.

¹³ 18 of these individuals occur on PTA lands and are not included in take estimates.

3.5.3.2 2011 Surveys

The data collected during the 2003-2007 botanical surveys (Table 3.1) was used to create a model (in conjunction with habitat type, species ranges, and moisture regime) to predict where within the Plan Area one is most likely to find Covered Species in unsurveyed areas. From this analysis, new areas to be surveyed were highlighted, and surveys were conducted in summer of 2011. A total of approximately 35 miles of transect were surveyed, primarily in the lower dry forest areas within the Plan Area, and additional transects were surveyed in the mauka areas abutting the Forest Bird Sanctuary (Figure 3.3). In addition, the proposed Kauila conservation unit was completely censused during these surveys (Table 3.3). The data collected during these surveys was used to update the plant population model and assist in developing more accurate take values for a number of the Covered Species (*please see section 5.3, Estimating Plan Related Impacts, for more information*).

Table 3.2 List of species and number of individuals found during 2011 botanical surveys.

Scientific Name	Common Name	# of Individuals
Endangered		
<i>Chrysodracon hawaiiensis</i>	Hala pepe	18
<i>Colubrina oppositifolia</i>	Kauila	87
<i>Nothoestrum breviflorum</i>	‘Aiea	118

Table 3.3 List of species and number of individuals found during the 2011 Kauila conservation unit re-survey.

Scientific Name	Common Name	# of Individuals
Endangered		
<i>Chrysodracon hawaiiensis</i>	Hala pepe	147
<i>Colubrina oppositifolia</i>	Kauila	645
<i>Nothoestrum breviflorum</i>	‘Aiea	5

3.5.4 Covered Species in the HCP

Plant Extinction Prevention Program

The Plant Extinction Prevention Program's mission is to protect Hawai'i's rarest native plants from extinction focusing on those species with fewer than 50 individuals remaining. Currently on Hawai'i Island, approximately 85 species are managed by the PEPP program by activities including: collection of fruits, cuttings, and seeds from each species for propagation and storage; monitoring of plants in the wild; surveying of additional areas for future conservation actions; minimization of threats to survival of individuals or populations (fencing, ungulate control); and propagation and reintroduction of plants into protected areas (Joan Yoshioka, personal communication, October, 2015). Those Covered Species which are considered PEP species are defined within this section. Of the 15 Covered Species in this HCP, five have designated PEP status (Table 3.4).

Critical Habitat Designation

Critical Habitat (CH) is defined in Section 3 of the ESA as: (1) The specific areas within the geographical area occupied by a species, at the time it is listed in accordance with the Act, on which are found those physical or biological features (a) essential to the conservation of the species and (b) which may require special management considerations or protection; and

(2) Specific areas outside the geographical area occupied by a species at the time it is listed, upon a determination that such areas are essential for the conservation of the species. In 2003, the USFWS designated critical habitat for 46 plant species on the Island of Hawai'i. Of those 46 species, eight species are Covered Species under this HCP. The USFWS is currently proposing a new CH designation for three additional species (*Bidens micrantha* ssp. *ctenophylla*, Uhiuhi, and *Isodendrion pyrifolium*) of which one of these species (Uhiuhi) is a Covered Species under this HCP. For those Covered Species with a CH designation within the Plan Area, maps showing critical habitat and exclosures locations are provided below.

3.5.4.1 *Asplenium peruvianum* var. *insulare*



Description: *Asplenium peruvianum* var. *insulare* is a fern of the spleenwort family (Aspleniaceae) with a short sub-erect stem. The leaf stalks are 5-15 cm long. The main axis of the frond is dull gray or brown, with two greenish ridges. The long and narrow fronds are thin-textured, bright green, 23-41 cm long, 2 cm wide above the middle, and pinnate with 20-30 pinnae or leaflets on each side. The pinnae are rhomboidal, 7 mm wide, and notched into two to five blunt lobes on the side towards the tip of the frond. The sori (spore-producing bodies) are close to the main vein of the pinna, with one to two on the lower side and two to four on the upper side. The Hawaiian fern species most similar to *A. peruvianum* var. *insulare* is *A. macraei*. The two can be distinguished by a number of characteristics, including the size and shape of the pinnae and the number of sori per pinna.

Historic and Current Distribution: *A. peruvianum* var. *insulare* was known historically from East Maui, where it was recorded from the north slope of Haleakalā and Kanahau Hill. At the time the taxon was federally listed in 1994, it was assumed extinct on Maui. In recent times, East Maui populations have been recorded within Kalialinui ahupua‘a on East Maui Watershed Partnership lands, in Waikamoi on private and federal (Haleakala National Park) lands (two populations with 18 individuals), and in the Hanawi Natural Area Reserve. In 2010, *A. peruvianum* var. *insulare* was estimated to contain approximately 17 individuals from Hanawi Natural Area Reserve and Waikamoi Preserve on Maui (USFWS 2012a). See Table 3.5 for a summary table of species distribution state-wide.

On the island of Hawai‘i, this fern was found historically below Kalaieha, Laumaia, Keanakolu, and Umikoa on Mauna Kea; Pu‘u Wa‘awa‘a on Hualālai; west of Keawewai, above Kīpuka Ahiu on Mauna Loa; and near Hilo. In the final recovery plan (USFWS 1998b) numbers had fallen to 278 statewide, the majority (nine subpopulations totaling 200 individuals) were found in the U.S. Army’s Pōhakuloa Training Area; extant populations at that time were located at Pu‘u Huluhulu, Pōhakuloa Training Area, Kulani Correctional Facility, Keauhou, the Mauna Loa Strip Road in Hawai‘i Volcanoes National Park, Kapapala Forest Reserve, Ka‘ū Forest Reserve, and the summit area of Hualālai. In 2010, the estimated statewide total of *A. peruvianum* var. *insulare* was 14 populations containing 603 to 948 individuals (USFWS 2012a). At Pu‘u Wa‘awa‘a, this species was only found in moist lava tubes or pit craters at 1,280-1,981 m elevation, with most

individuals occurring above 1,676 m. During the HCP surveys 64 individuals were found within the Plan Area.

Habitat: This fern is found on the island of Hawai‘i in ‘Ōhi‘a dry montane forest, ‘A‘ali‘i dry montane shrubland, Naio/ Māmane dry montane forest, ‘Ōhi‘a /Koa forest as well as subalpine dry forest and shrubland. *A. peruvianum* var. *insulare* grows almost exclusively in lava tubes, pits, deep cracks, and lava tree molds, with at least a moderate soil or ash accumulation, and is associated with mosses and liverworts. This fern has been found growing infrequently on the interface between younger lava flows and much older pāhoehoe lava or ash deposits. The population recently found on Maui is growing in montane wet ‘Ōhi‘a forest in a rocky gulch with other species of ferns. Although this plant is found in habitats with three different moisture regimes, the micro-habitat for *A. peruvianum* var. *insulare* is fairly consistent. The fern generally occurs in areas that are moist and dark; its relatively specialized habitat requirements may account for its apparently patchy distribution. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown. Critical Habitat has been designated for this species, however, the CH is outside of the Plan Area (USFWS 2003c).

3.5.4.2 Hala pepe (*Chrysodracon hawaiiensis*)



Description: Hala pepe, in the Asparagus family (Asparagaceae), is a branching tree, 5 to 6 m tall, with leaves spirally clustered at the tips of branches and leaving large brown leaf scars as they fall off. The leaves measure 23 to 38 cm long and 1.4 to 2.7 cm wide. Flowers are numerous in terminal clusters with a main stalk 6 to 13 cm long and individual flower stalks 5 to 12 mm long. The three sepals and three petals of the flower are similar and pale yellow, 33 to 43 mm long, with a constricted base. The fruit is a red berry about 10 to 13 mm long. This species differs from other Hawaiian species in this genus by its pale yellow flowers, the size of the flowers, the length of the constricted base of the flower, and the width of the leaves (USFWS 1996a, Wagner et al. 1999).

Historic and Current Distribution: Historically, Hala pepe was found ranging from the Kohala mountains to Ka‘ū. Nine populations are currently known: one in the Kohala mountains at Pu‘u Kamoā (2 individuals); four from Pu‘u Wa‘awa‘a (2 populations of 200 individuals and 50-100 individuals), Ka‘ūpūlehu (no information available), and Kaloko (11 individuals); two in the South Kona area at Manukā and Kahuku (11 individuals), one extant population at the Kipahoe Natural Area Reserve; and two populations in Hawai‘i Volcanoes National Park (HVNP). As of 2009, there were 6 to 9 populations containing a total of 300 to 400 individuals (USFWS 2012d). During the HCP surveys, 299 individuals were within the Plan Area. See Table 3.5 for a summary table of species distribution state-wide.

Habitat: Hala pepe typically grows on open ‘a‘ā lava in diverse lowland dry forests at elevations between 300 and 800 m. Associated taxa include ‘Ōhi‘a, Lama, Māmane, Alahe‘e, Hue hue, Naio, Olopua, Kulu‘i, ‘Ilima, Wiliwili, ‘Iliahi, ‘Ūlei, and fountain grass as a dominant ground cover, as well as four federally endangered species: Uhiuhi, Kauila, ‘Aiea, *Neraudia ovata*, and species of concern, including Pua pilo (*Capparis sandwichiana*) and Ko‘oko‘olau (*Bidens micrantha* ssp. *ctenophylla*). Critical habitat was designated for this species in 2003 (Figure 3.4)(USFWS 2003c).

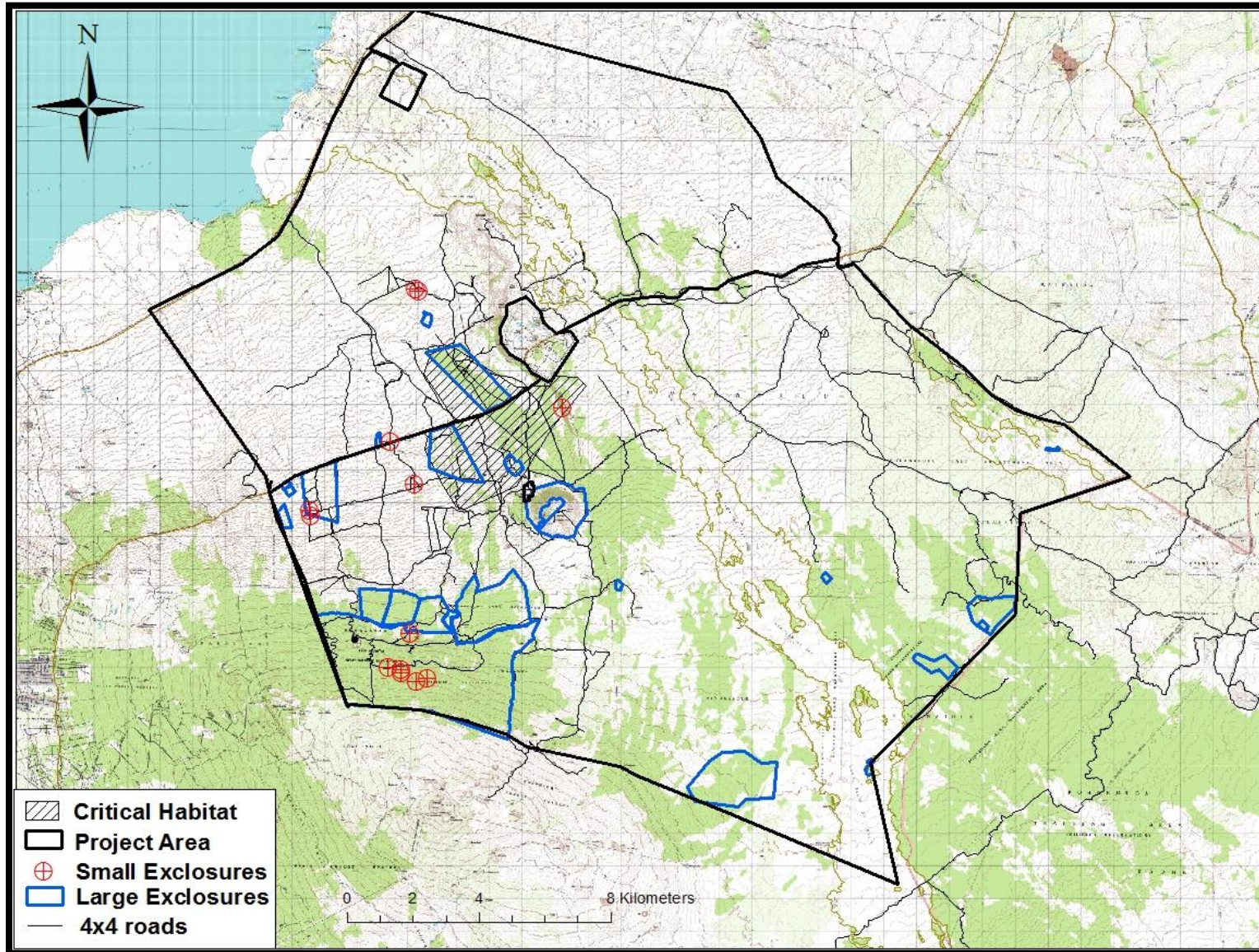


Figure 3.4 Critical habitat for Hala pepe within the Plan Area.

3.5.4.3 *Kauila (Colubrina oppositifolia)*



Description: *Kauila*, a member of the buckthorn family (Rhamnaceae) is a tree approximately 5-13 m tall, with extremely hard red wood. Opposite, oval-shaped leaf blades are 6-12 cm long and 3-7 cm wide. Leaf blades are thin, dull green on the upper surface, and olive green beneath. Two kinds of glands occur on the lower surface: small black glands near the margin and small glandular projections in the axil of the leaf vein. Leaf stalks are 1.4-3 cm long. Lance-shaped stipules are fused at the base of each pair of leaves. Ten to 12 flowers are arranged on a flower cluster stalk 3-8 mm long. Each flower is subtended by a flower stalk 2-3 cm long, which increases in length as the fruit matures. Five sepals are triangular and about 1.5-2 mm long. Five green-yellow petals are about 1.5 mm long. Fruits are brown, almost round, about 8-11 mm long, and are explosively dehiscent, discharging oval or oblong, black, shiny, hump-back seeds, 6-8 mm long and 4-5 mm in diameter. This species is readily distinguished from the other species in Hawai‘i by several characters: opposite leaf position, dull leaf surface, and entire leaf margins (Wagner et al. 1999).

Historic and Current Distribution: *Kauila* is known from O‘ahu, Maui and Hawai‘i Island. Historic populations are known from the central and southern Waianae Mountains on O‘ahu, and from the Kohala mountains; western, southwestern, and southern slopes of Mauna Loa; and northern slopes of Hualālai on the island of Hawai‘i Island. On Maui, there are two wild mature individuals located within the Nature Conservancy’s Kapunakea Preserve. Today, there are seven populations containing at least 54 mature wild individuals on O‘ahu. There are approximately two to five populations containing 1,190 to 1,209 wild individuals on the island of Hawai‘i (USFWS 2015f). See Table 3.5 for a summary table of species distribution state-wide.

This species was found primarily at 488-853 m elevation in Pu‘u Wa‘awa‘a, with some individuals at higher elevation on the Pu‘u Wa‘awa‘a cinder cone, and three individuals found in Pu‘u Anahulu at 732 m. Previously there were thought to be 200-300 individuals at Pu‘u Wa‘awa‘a, however, recent HCP surveys indicate the population at Pu‘u Wa‘awa‘a consists of at least 739 individuals.

Habitat: *Kauila* occurs in lowland dry and mesic forests. The dominant species of these forests is *Lama*. Individuals are found at elevations between 240-910 m, sometimes on ‘a‘ā lava flows and

associated with Alahe'e and 'Ohe makai. Critical habitat was designated for this species in 2003 (Figure 3.5)(USFWS 2003c).

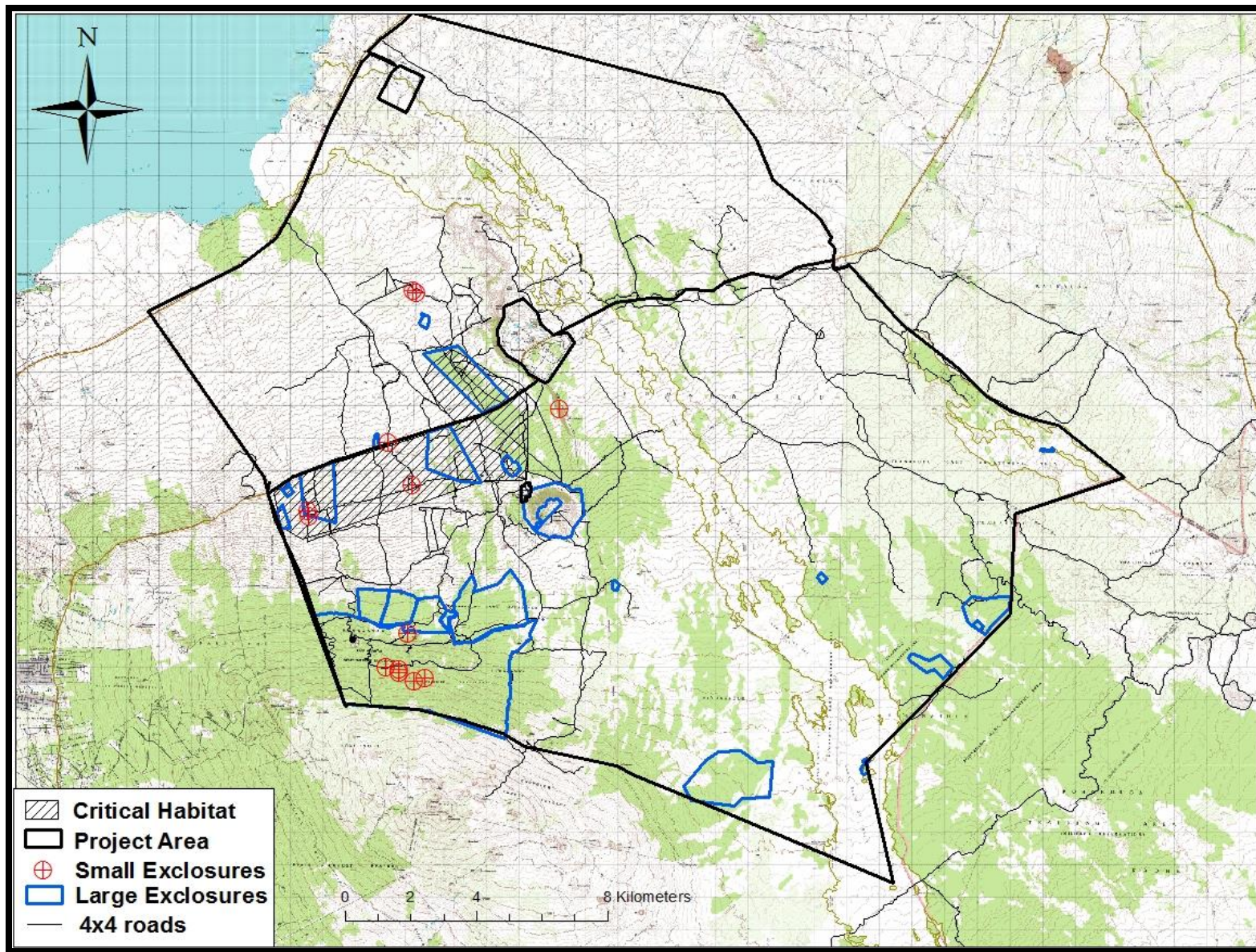


Figure 3.5 Critical habitat for Kauila within the Plan Area.

3.5.4.4 Honohono (*Haplostachys haplostachya*)



Description: Honohono is an erect sub-shrub in the mint family (Lamiaceae) growing up to 1.5 m. The leaves are fleshy, narrowly cordate and the upper surfaces are green, rugose and densely puberulent. The lower leaf surfaces are densely white tomentose. The inflorescence is racemose with white tubular flowers. Reproduction is through seed and basal sprouting (Wagner et al. 1999).

Historic and Current Distribution: Honohono was once present on the islands of Kauai, Maui, and Hawai‘i. Currently Honohono is only known to occur on Hawai‘i Island. It is found at Pōhakuloa Training Area and at Pu‘u Anahulu. As of 2010, the listed census for Honohono is two populations at Pu‘u Nohonaohae and Keamuku, containing over 10,000 individuals (USFWS 2012b). In the Plan Area, Honohono is found at 1,280 m elevation on a Mauna Kea lava flow (14,000-65,000 years old), in a kīpuka on the Keamuku lava flow. These are the only known plants that occur on State lands. During HCP plant surveys, a total of 80 individuals were located within the Plan Area. See Table 3.5 for a summary table of species distribution state-wide.

Habitat: Honohono grows in dry exposed areas on lava, shallow soils, and lava outcrops. Historic accounts indicate it was once found as component within the upper forest zone along with stunted vegetation (USFWS 2003c). At PTA, this species is found in ‘Akoko tree land, open ‘Ōhi‘a forest with dense shrub understory, and open ‘A‘ali‘i mixed shrubland. This species has been noted growing almost exclusively on Mauna Kea lava flows (USFWS 2003a). Critical habitat has not been designated for this species.

3.5.4.5 Ma‘o hau hele (*Hibiscus brackenridgei* ssp. *brackenridgei*)



Description: Ma‘o hau hele is a shrub in the Malvaceae family and can sometimes become a small tree growing up to 9 m tall. When planted as an ornamental, it is most often a 0.91 to 4.5 meters tall shrub with a diameter of 2.5 to 4.5 meters. Young plants have smooth tan trunks; the trunks of older plants have a wrinkled appearance. The fuzzy leaves have toothed edges; three, five, or seven lobes; and are up to 15 cm long and equally wide. The large flowers are 10 to 15 cm in diameter. They are yellow, generally with a maroon center, and form singly or in small clusters at the ends of the branches. The staminal column is yellow. Spring through early summer is the main blooming season with occasional flowers during the rest of the year. It is native to dry forests and shrub lands at elevations from 121 to 792 m.

Historic and Current Distribution: Ma‘o hau hele (*Hibiscus brackenridgei* ssp. *brackenridgei*) is the subspecies on the islands of Lāna‘i, Maui, and Hawai‘i. On Lāna‘i there are only two or three individuals in the Keomuku Road area. On Maui there is one population recorded in East Maui and one population in West Maui on private land. The Island of Hawai‘i has two wild populations of Ma‘o hau hele. One population referred to as the Lalamilo population, is located just outside of Waimea. The second population is found in a one acre enclosure on the top of Pu‘u Anahulu bluff across from the hunter check station at Pu‘u Wa‘awa‘a at 731 m elevation. During HCP surveys 65 Ma‘o hau hele individuals were found within the Plan Area. See Table 3.5 for a summary table of species distribution state-wide.

Habitat: Ma‘o hau hele occurs in lowland dry to mesic forest and shrubland from 130-800 m in elevation. Associated plant species include ‘A‘ali‘i, Alahe‘e, Wiliwili, ‘Ohe makai, and ‘Ilima. Critical habitat was designated for this species in 2003 (Figure 3.6) (USFWS 2003c).

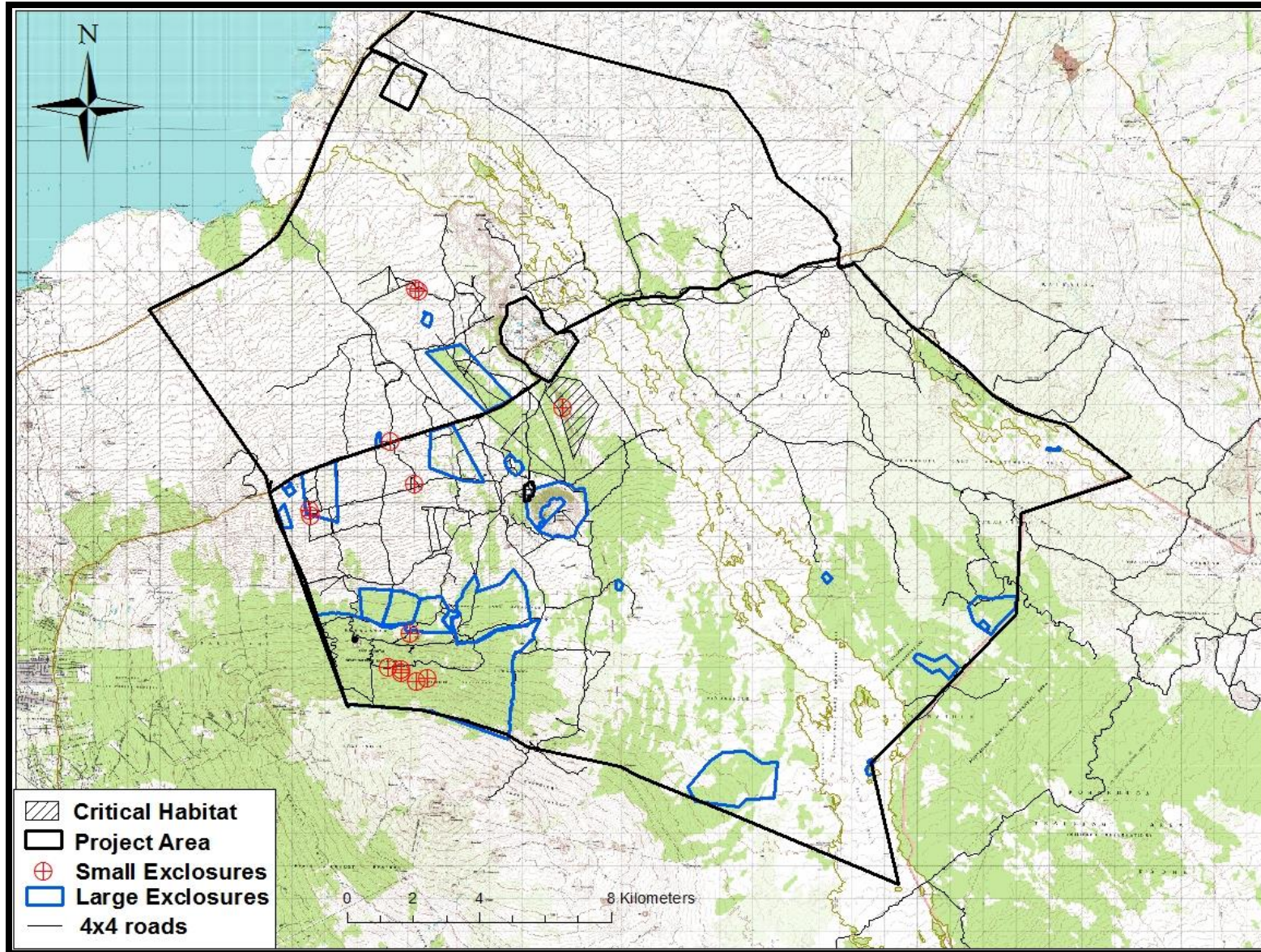


Figure 3.6 Critical habitat for Ma'o hau hele within the Plan Area.

3.5.4.6 Koki‘o (*Kokia drynarioides*)



Description: A tree in the Malvaceae family grows to heights of 8 m tall, with shallowly lobed leaves and with large, ornamental, scarlet flowers. Koki‘o is one of four species in the *Kokia* genus and the only one found on the island of Hawai‘i. The sap of this rare tree has been used by Native Hawaiians to make red dyes for fish nets and its bark was used medicinally. In the early 1900’s, botanists became concerned about the survival of this species and collected several pounds of seed that were later distributed to various gardens and arboreta for germination. Despite this, Koki‘o has become increasingly rare in the wild. This decline may have had severe impacts on organisms that rely on the species, such as the now endangered nectar drinking honeycreepers which depend on these trees for food.

Historic and Current Distribution: Occurs in native dry forests on the island of Hawai‘i on rough lava with a thin, extremely well drained soil at elevations of 455 to 1,915 meters. Currently, two extant populations remain: the first at Ka‘ūpūlehu containing one mature individual and the second population at Kīpuka Nene containing a single surviving mature individual (USFWS 2009). In the Plan Area, the last four individuals occur in two fences along the edge of the Ka‘ūpūlehu flow above the 25 mile road entrance to Pu‘u Wa‘awa‘a. Koki‘o has been outplanted in a number of exclsoures across the Plan Area, including Hauaina, Kīpuka Oweowe, FBS, and PWWCCA. This species is considered a PEPP species (Table 3.4). See Table 3.5 for a summary table of species distribution state-wide.

Habitat: Associated native species include ‘Āweoweo, ‘A‘ali‘i, Hala pepe, Wiliwili, Kulu‘i, ‘Ohe makai, Māmane, and Maua (*Xylosma hawaiiense*). Alien species that have invaded this habitat include fountain grass, tree tobacco (*Nicotiana glauca*), fireweed (*Senecio madagascariensis*) and lantana (*Lantana camara*). Critical habitat was designated for this species in 1984 (Figure 3.7) (USFWS 1984).

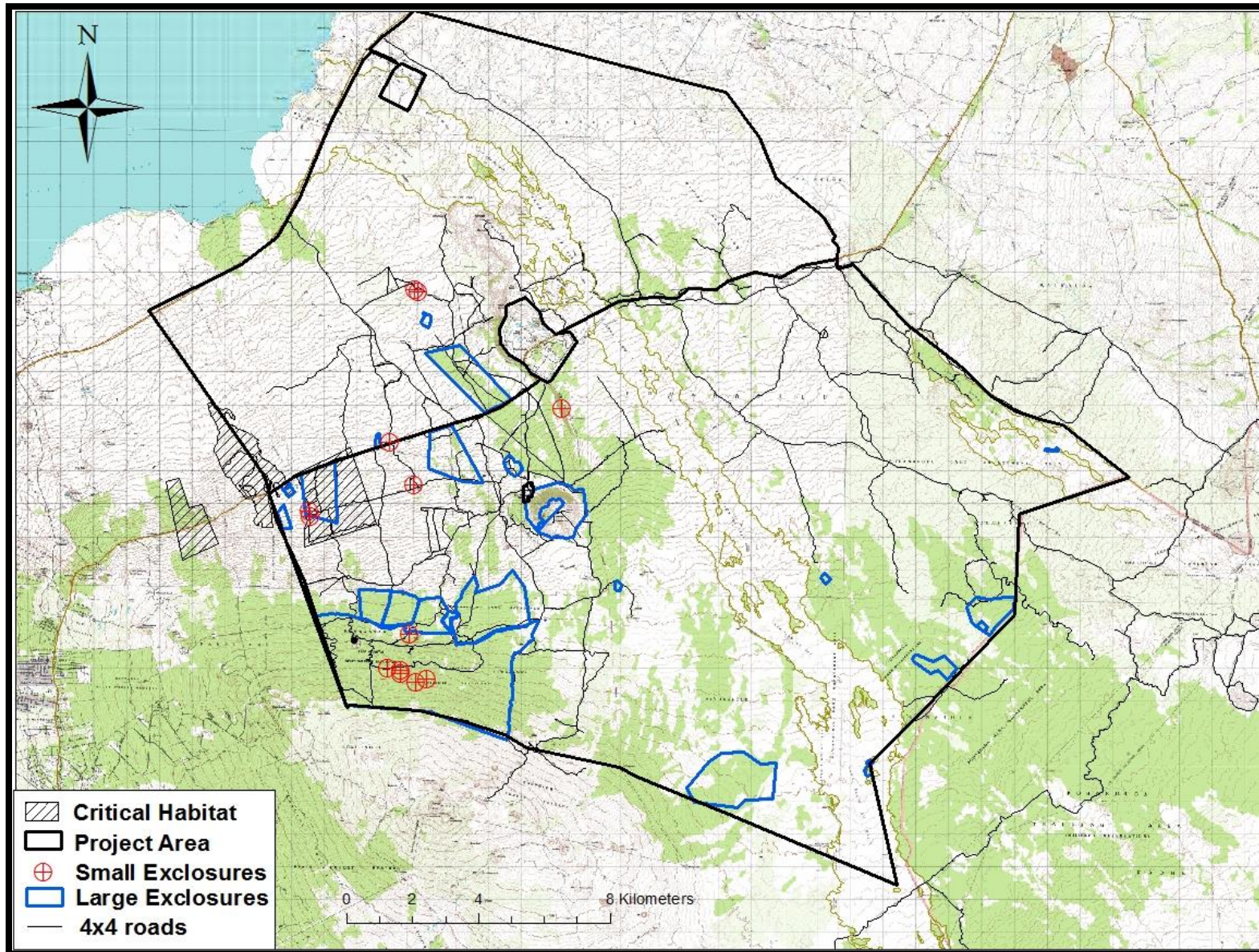


Figure 3.7 Critical habitat for Koki'o within the Plan Area.

3.5.4.7 Uhiuhi (*Mezoneuron kavaense*)



Description: Uhiuhi, a member of the pea family (Fabaceae), is a tree that can grow up to 10 meters tall, with trunks that have dark gray bark with rough rectangular or oblong plates. The flowers are perfect (with both male and female organs) with a pink to rose calyx and red anthers borne in terminal racemes that are pink to red in color. Uhiuhi has pink seed pods that are winged on one side, making this a very attractive tree (Wagner et al. 1999).

Historic and Current Distribution: Uhiuhi is endemic tree to the Hawaiian Islands and was once widespread on the islands of Kaua‘i (Waimea Canyon), O‘ahu (Wai‘anae Mountains), west Maui, North Kona District, Hawai‘i, and Lāna‘i. Today, Uhiuhi is extinct on Lāna‘i and is now found only on O‘ahu (Central Wai‘anae Mountains), and Hawai‘i island (Hualālai). On Kaua‘i, the species was rediscovered as one wild plant was recently found in Waimea Canyon (Letman 2012). On O‘ahu, there are two populations containing five wild mature individuals and two seedlings. On Hawai‘i Island, Uhiuhi is found on state lands at Pu‘u Wa‘awa‘a, on private land in North Kona, and on Private lands in Waikoloa in South Kohala. There are approximately 11 occurrences containing 99 wild individuals of Uhiuhi on Kaua‘i, O‘ahu, Lāna‘i, and Hawai‘i (USFWS 2015a). During HCP surveys, 48 Uhiuhi were within the Plan Area. See Table 3.5 for a summary table of species distribution state-wide.

Habitat: Uhiuhi is restricted to dry or mesic forests between 80 to 920 m elevations. Associated native species include ‘A‘ali‘i, Lama, ‘Ōhi‘a, Alahe‘e, Wiliwili, ‘Āweoweo, and Kauila. Critical habitat has been proposed but not yet designated for this species (Figure 3.8).

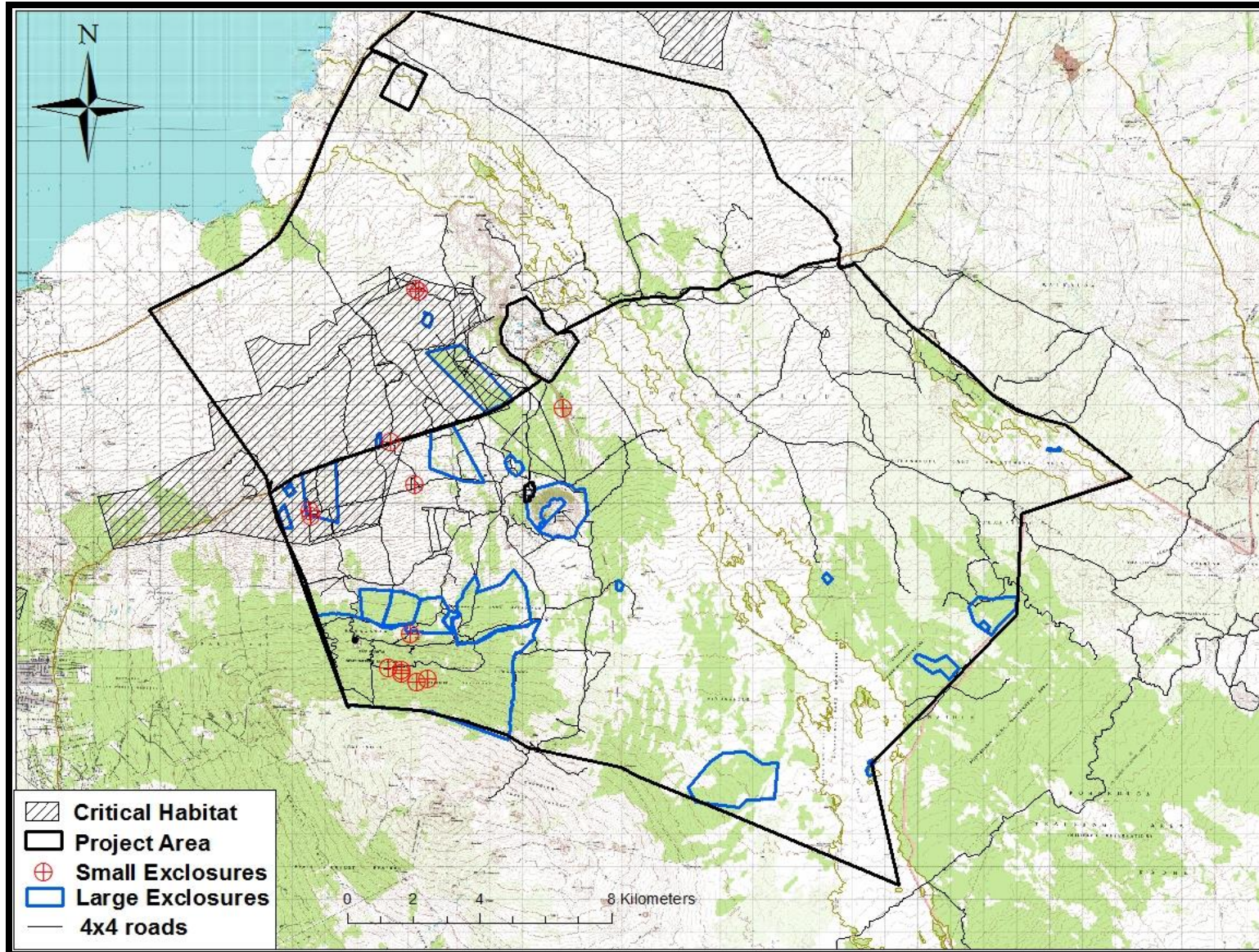


Figure 3.8 Proposed critical habitat for Uhihi within the Plan Area.

3.5.4.8 *Neraudia ovata*



Description: In the nettle family (Urticaceae), this species is a sprawling or rarely erect shrub to a small tree, with stems 1 to 3 m long, and branches bearing short, somewhat erect hairs. The alternate, thin, stalked leaves are smooth-margined, grayish on the undersurface, 5 to 14 cm long and 2 to 6.5 cm wide, and have spreading, curved, nearly translucent hairs. Male and female flowers are found on separate plants. Male flowers have extremely short stalks and a densely hairy calyx. Female flowers have no stalks and a densely hairy, boat-shaped calyx. The fruit is an achene (a dry, one-seeded fruit that does not open at maturity). This species is distinguished from others in this endemic Hawaiian genus by the density, length, and posture of the hairs on the lower leaf surface; smooth leaf margin; and the boat-shaped calyx of the female flower.

Historic and Current Distribution: Historically, *Neraudia ovata* was found from North Kona all the way to Ka‘ū. There are currently five extant known plant locations. One population of three individuals was known from privately owned land in Kaloko, North Kona. The second population is located at the boundary of PTA and Pu‘u Anahulu, on state managed land (Shaw et al. 1997) and was resurveyed by the HCP botanical crew during the 2003 – 2007 surveys. A third population, which is located within PTA, in the fiscal year 2013, there were approximately 75 individuals. One individual is known to occur in the Manuka Natural Area Reserve (DOFAW Staff), and a final population has been located in windward Kohala. This species is considered a PEP species (Table 3.4). The number of wild individuals has decreased from 150 individuals reported in 2008 to 90 individuals in 2015 (USFWS 2015b). See Table 3.5 for a summary table of species distribution state-wide.

Habitat: *Neraudia ovata* grows in open ‘Ōhi‘a and Māmane dominated lowland and montane dry forests at elevations of 115 m at Kaloko and 1,325 and 1,520 m at Pōhakuloa Training Area. Associated taxa include ‘Ohe makai, Naio, Huehue, Kōlea species, and christmas berry (*Shinus terebinthefolius*), as well as the federally endangered ‘Aiea and Hala pepe, and other species of concern, including Pua pilo, *Fimbristylis hawaiiensis*, and Ko‘oko‘olau (*Bidens micrantha* ssp. *Ctenophylla*). Critical habitat was designated for this species in 2003 (Figure 3.9) (USFWS 2003c).

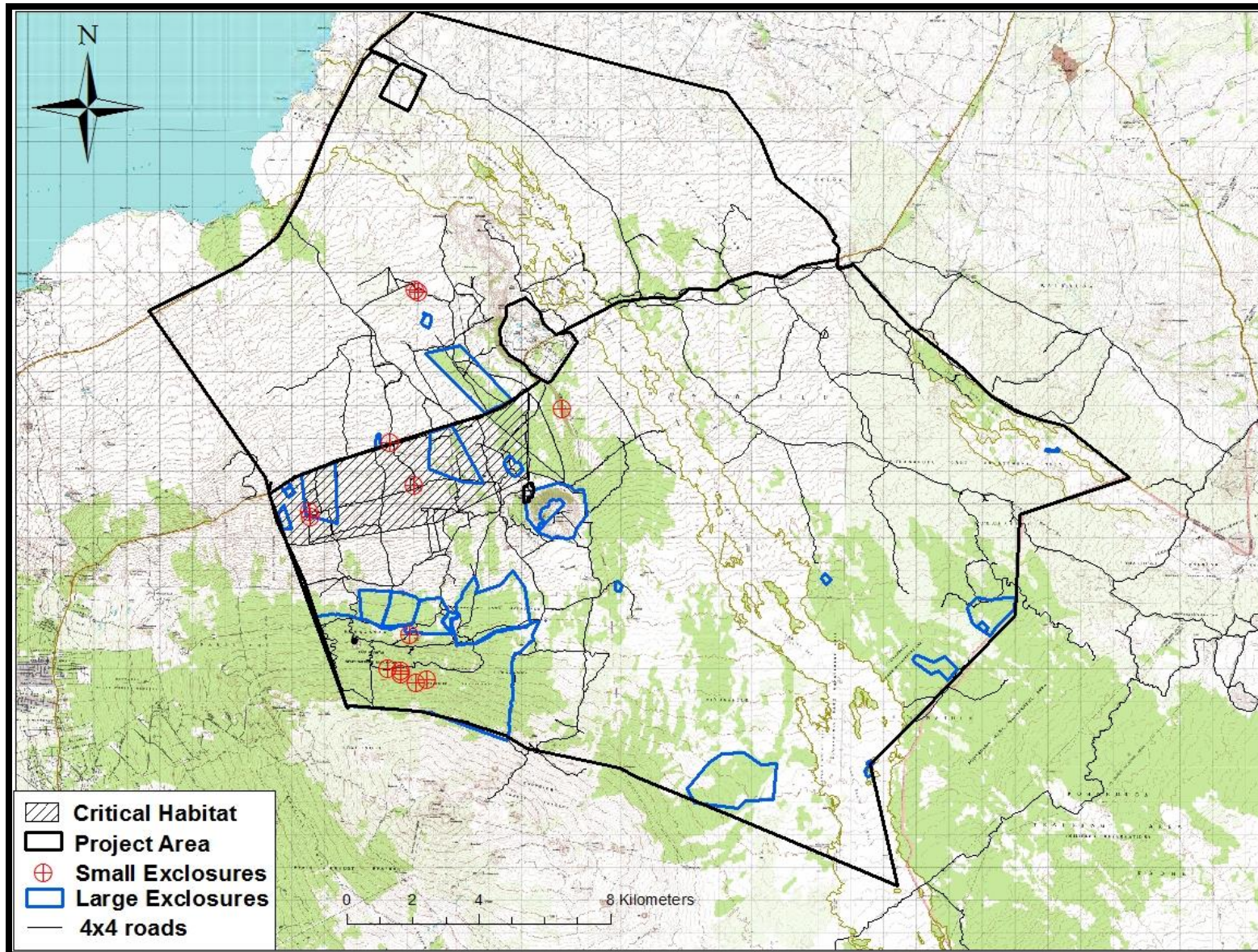


Figure 3.9 Critical habitat for *Neraudia ovata* within the Plan Area.

3.5.4.9 ‘Aiea (*Nothocestrum breviflorum*)



Description: ‘Aiea is a stout tree that grows up to 10-12 m it is in the night shade family (Solanaceae). The trunk, is up to about 45 cm in diameter, and has a soft, sappy wood with dark brown bark. Oblong to elliptic, toothless, stalked leaves, 5-12 cm long and 3-6 cm wide are generally confined to the ends of the branches and are seasonally shed. In texture, they are relatively thick and papery. The upper leaf surface is glabrous (smooth) to sparsely whitish pubescent (downy), and the lower surface is often densely whitish pubescent. Several to numerous flowers appear in clusters at the tips of shortened, spur-like branches. Each flower is subtended by its own stalk (pedicel) 4-10 mm long. The 4-lobed, tube-shaped calyx, 6-11 mm long, is split on one side. Green-yellow, 4-lobed petals are fused at the base and generally are enclosed in the calyx. The lobes are hairy on the outside. Fruits remain enclosed by the calyx and are orange-red, round berries about 6-8 mm in diameter.

This species is distinguished from other Hawaiian members of the genus by leaf shape, number of flowers (more than three) in the flower clusters at tips of short spur-like branches, and the fruit remaining enclosed in the calyx (Symon 1990).

Historic and Current Distribution: ‘Aiea is known from the southern Kohala mountains, the western, southern, and eastern slopes of Mauna Loa, and the northern slopes of Hualālai, Hawai‘i. Since 1975, a number of populations have been identified on the western side of Hawai‘i Island from South Kohala to Kamaoa-Puueo. In 2010, there were an estimated 10 wild populations of ‘Aiea containing less than 150 total individuals (USFWS 2012c). Recent HCP surveys indicate 156 individuals are known to occur within the Plan Area. See Table 3.5 for a summary table of species distribution state-wide.

Habitat: Habitats of ‘Aiea is lowland dry forest, montane dry forest, and montane mesic forest dominated by ‘Ōhi‘a, Koa, or Lama. Individuals occur on ‘a‘ā lava substrates at elevations ranging from 180 to 1,830 m (Gagne and Cuddihy 1990, Symon 1990). Associated taxa include ‘Iliahi, Uhiuhi, and Wiliwili. Critical habitat was designated for this species in 2003 (Figure 3.10) (USFWS 2003c).

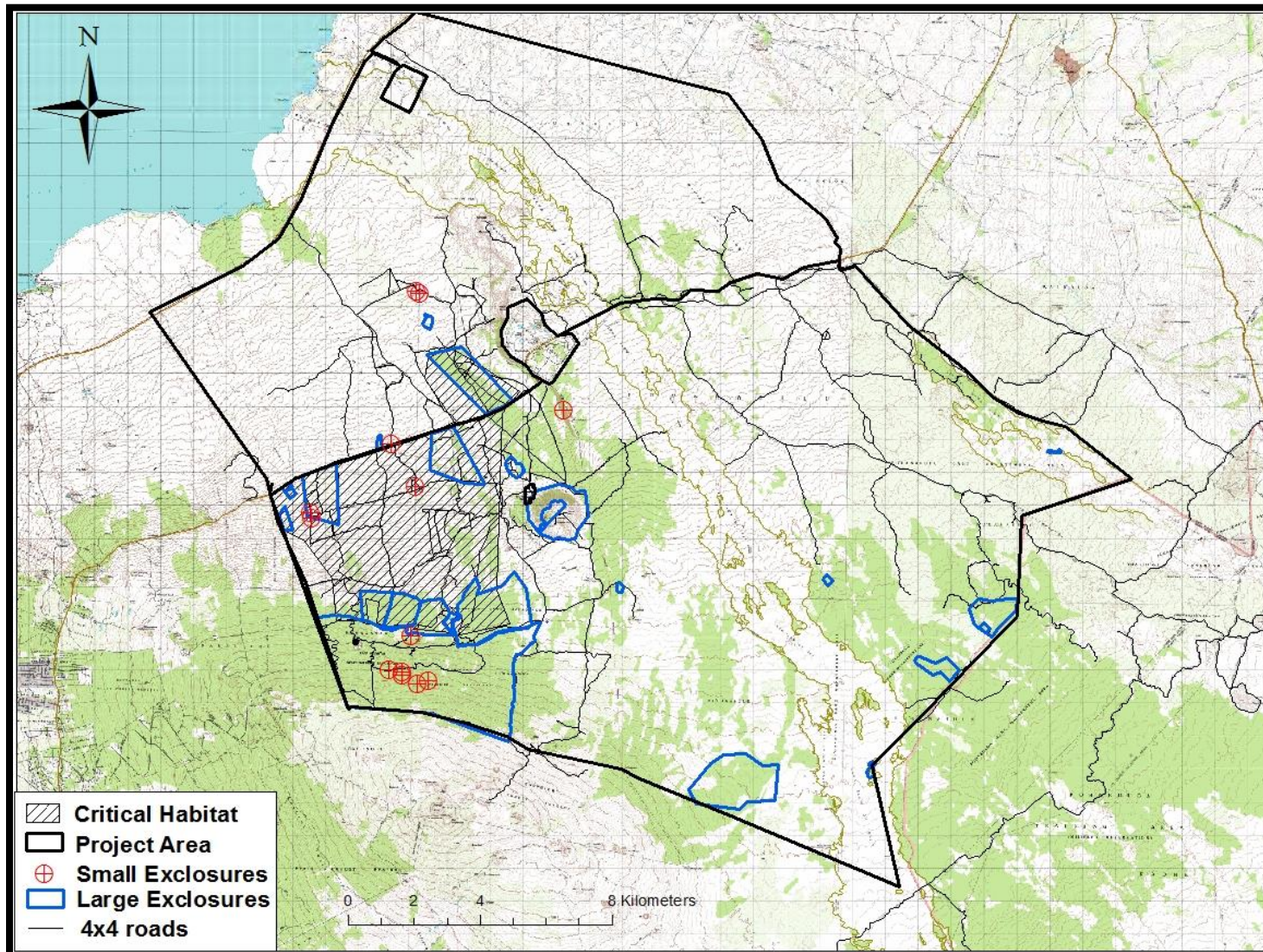


Figure 3.10 Critical habitat for 'Aiea within the Plan Area.

3.5.4.10 Po‘e (*Portulaca sclerocarpa*)



Description: Po‘e is a perennial with a fleshy, tuberous tap root that becomes woody with maturity (Wagner et al. 1999). Stems are prostrate or ascending and the leaves, 8-12 mm long and 1.5-2.5 mm wide, are narrowly oblance-shaped to linear, almost round in cross section, succulent, grey-green, and stalkless. Dense tufts of yellow-brown hairs occur in the axil between stem and leaf. Three to six flowers occur at the end of a stem and from a dense flower cluster. Flowers are white, pink, or pink with white base petals.

Historic and Current Distribution: Known from the islands of Hawai‘i and Lāna‘i. Populations were found on an islet off of the coast of Lāna‘i, and the Kohala Mountains, the northern slopes of Hualālai, the northwestern slopes of Mauna Loa, and near Kīlauea Crater on Hawai‘i Island (USFWS 1996a). As of 2010, there were an estimated 12 extant populations statewide of Po‘e containing more than 3,000 individuals (USFWS 2012e). One individual was found in upper Pu‘u Anahulu in January 2014 by the Hawai‘i Island PEPP Coordinator. See Table 3.5 for a summary table of species distribution state-wide.

Habitat: This species occurs in montane dry shrubland. The taxon often is found on bare cinder, near steam vents, and in open ‘Ōhi‘a dominated woodlands, at elevations between 1,030 and 1,628 m (Gagne and Cuddihy 1990, Wagner et al. 1999). Associated taxa are Māmane, ‘Ōhi‘a, and Naio (USFWS 1996a). Critical habitat was designated for this species in 2003; however CH does not occur within the Plan Area.

3.5.4.11 Hawaiian Catchfly (*Silene lanceolata*)



Description: Hawaiian Catchfly is a sub-shrub with erect to ascending stems 15-50 cm long. Flowers are white and occur in open cymes. Leaves are linear to lanceolate, and ciliate toward the base but otherwise glabrous (Wagner et al. 1999).

Historic and Current Distribution: This plant is known from Moloka‘i, O‘ahu, and Hawai‘i; historically also known from Kaua‘i and Lāna‘i. On island Hawai‘i, within the Pōhakuloa Training Area populations of Hawaiian Catchfly are found along the western border of the military impact area. Approximately 10,394 individuals are found within 18 different areas of the Pōhakuloa Training Area. On O‘ahu, there were four known populations in 2003, with 62 individuals in Koi‘ahi Gulch and Waianae Kai on Federal and State lands. On Moloka‘i, from 1987 to 2001, 50 to 100 individuals of Hawaiian Catchfly were observed in Makolelau Gulch between 792 and 927 meters (USFWS 2010). During HCP surveys, 235 individuals were within the Plan Area. See Table 3.5 for a summary table of species distribution state-wide.

Habitat: Occurs from 330-1,900 m in dry to mesic shrubland on Moloka‘i, Kaua‘i, Lāna‘i, and Hawai‘i (Wagner et al. 1999). The populations on the island of Hawai‘i grow in two dry habitat types: shrubland dominated by dense Naio, Māmane, Pūkiawe with ‘A‘ali‘i, Pilo, and fountain grass; and on ‘a‘ā lava in a former ‘Akoko forest now converted to fountain grass grassland with ‘A‘ali‘i, Māmane, Naio, and ‘Āweoweo. Critical habitat was designated for this species in 2012; however CH does not occur within the Plan Area.

3.5.4.12 Pōpolo kū mai (*Solanum incompletum*)



Description: Pōpolo kū mai is a woody shrub in the nightshade family (Solanaceae) that grows up to 3 m tall with prominent reddish prickles scattered to abundant on stems and leaves. The oval leaves measure 10 to 15 cm long by about 7 cm wide. The leaf margins are lobed with one to four lobes on each side. Numerous flowers grow on loose branching clusters with each flower on a stalk about 9 mm long. The star-shaped flowers are white.

Historic and Current Distribution: This short lived perennial shrub is endangered and is historically known to occur from 600-2,200 m on the islands of Maui, Lāna‘i, Kaua‘i, Moloka‘i, and Hawai‘i. There are currently no known populations on Lāna‘i, Moloka‘i, or Maui. Until recently this species was thought to be extinct, however, it was rediscovered on Hawai‘i Island. As of 2011, an estimated 75 individuals of Pōpolo kū mai are known to occur in PTA, Pu‘u Anahulu, and Pu‘u Wa‘awa‘a (USFWS 2015c). During HCP surveys, 13 individuals were found within the Plan Area. This species is considered a potential PEP (POP) species (Table 3.4). See Table 3.5 for a summary table of species distribution state-wide.

Habitat: This plant occurs in dry and mesic shrublands and forests on ridges and in gulches. On Hawai‘i island, it occurs on cinder cones or on older lava flows. Critical habitat was designated for this species in 2003 (Figure 3.11)(USFWS 2003c).

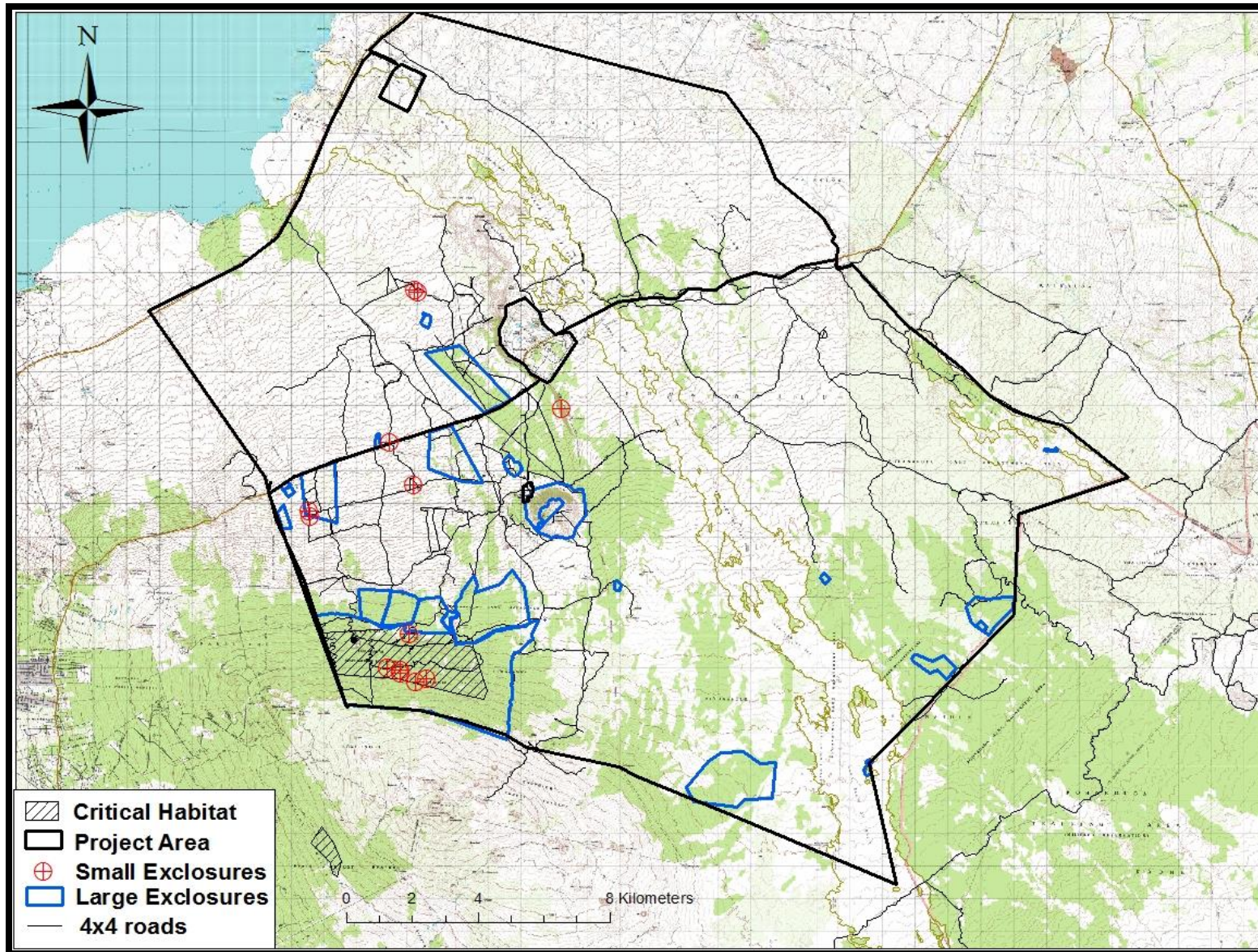


Figure 3.11 Critical habitat for Pōpolo kū mai within the Plan Area.

3.5.4.13 *Stenogyne angustifolia*



Description: A member of the mint (Lamiaceae) family, this vine may sprawl on the ground for a portion of its length prior to becoming erect, but may also become a climber. It has thin oval finely toothed leaves, up to 5 cm long and 1.3 cm wide. The narrow, tubular flowers are approximately 1.9 cm long and grow at the base of the leaves. Flower color varies from yellow to red to purple and has a short lower lobed lip and a long upper lobe. The pale colored fruits become dark when mature.

Historic and Current Range: Historically, the species was known from the islands of Moloka‘i, Maui, and Hawai‘i. *S. angustifolia* was presumed extinct until fewer than ten individuals were rediscovered in 1977 at Kīpuka Kalawamauna, located on the northwestern side of PTA, this site remains the largest extant population for the species (USFWS 2012f). Currently, estimated 5,000-7,500 individuals occur only on the Island of Hawai‘i, at Pōhakuloa Training Area (USFWS 2003a). During the HCP surveys 98 individuals of *S. angustifolia* were located within the Plan Area. See Table 3.5 for a summary table of species distribution state-wide.

Habitat: *S. angustifolia* grows on relatively flat lava flows and shallow soils in semi-arid shrublands and ‘Ōhi‘a woodlands at an elevation of 1,555-2,150 m. The species has been described as abundant on various aged lava or rock outcrops associated with the following vegetation: *Eragrostis* grassland, *Chenopodium* shrubland, ‘Akoko, open ‘Ōhi‘a forest, ‘A‘ali‘i/Naio shrubland, and mixed native shrubland. Critical habitat has not been designated for this species.

3.5.4.14 A‘e (*Zanthoxylum dipetalum* var. *tomentosum*)



Description: A‘e (*Z. dipetalum* var. *tomentosum*), endemic to Hawai‘i Island, is in the citrus family (Rutaceae), is a thornless tree 4 to 15 m tall with a trunk up to 30 cm in diameter. It has alternate leaves comprised of three to seven leathery, elliptical, gland-dotted, smooth-edged leaflets usually 6 to 36 cm long and 2.5 to 13.5 cm wide. The undersurface of the leaflets is densely covered with fine, short hairs, and the lowest pair of leaflets is often strongly reduced. The stalks of the side leaflets have one joint each, and the stalk of the terminal leaflet has two joints. Flowers are usually either male or female, and usually only one sex is found on a single tree. Clusters of 5 to 15 flowers, 9 to 18 mm long, have a main flower stalk 10 to 40 mm long and individual flower stalks 3 to 8 mm long. Each flower has four broadly triangular sepals about 1 to 1.5 mm long and two or four yellowish-white petals, sometimes tinged with red, 6 to 10 mm long. The fruit is an oval follicle (dry fruit that opens along one side) 15 to 33 mm long, containing one black seed about 10 to 26 mm long. This variety is distinguished from *Zanthoxylum dipetalum* var. *dipetalum* by the hairs on the undersurface of the leaflets. It is distinguished from other Hawaiian species of the genus by its reduced lower leaflets, the presence of only one joint on some of the leaflet stalks, and the large seeds (USFWS 1996a).

Historic and Current Distribution: Only one population of A‘e (*Z. dipetalum* var. *tomentosum*) has ever been known, located at Pu‘u Wa‘awa‘a. In 2011, there were 13 wild individuals at Pu‘u Wa‘awa‘a. During 2013, two wild individuals at Pu‘u Wa‘awa‘a were noted as dead, bringing the total to 11 individuals. See Table 3.5 for a summary table of species distribution state-wide. This species is considered a PEPP species (Table 3.4).

Habitat: A‘e (*Z. dipetalum* var. *tomentosum*) grows in degraded ‘Ōhi‘a dominated montane mesic forest, often on ‘a‘ā lava, at elevations between 915 and 1,040 m. Associated species include Māmane, Lama, ‘Āla‘a (*Pouteria sandwicensis*), ‘Iliahi, Kōlea, and Kōpiko. Critical habitat was designated for this species in 2003 (Figure 3.12) (USFWS 2003c).

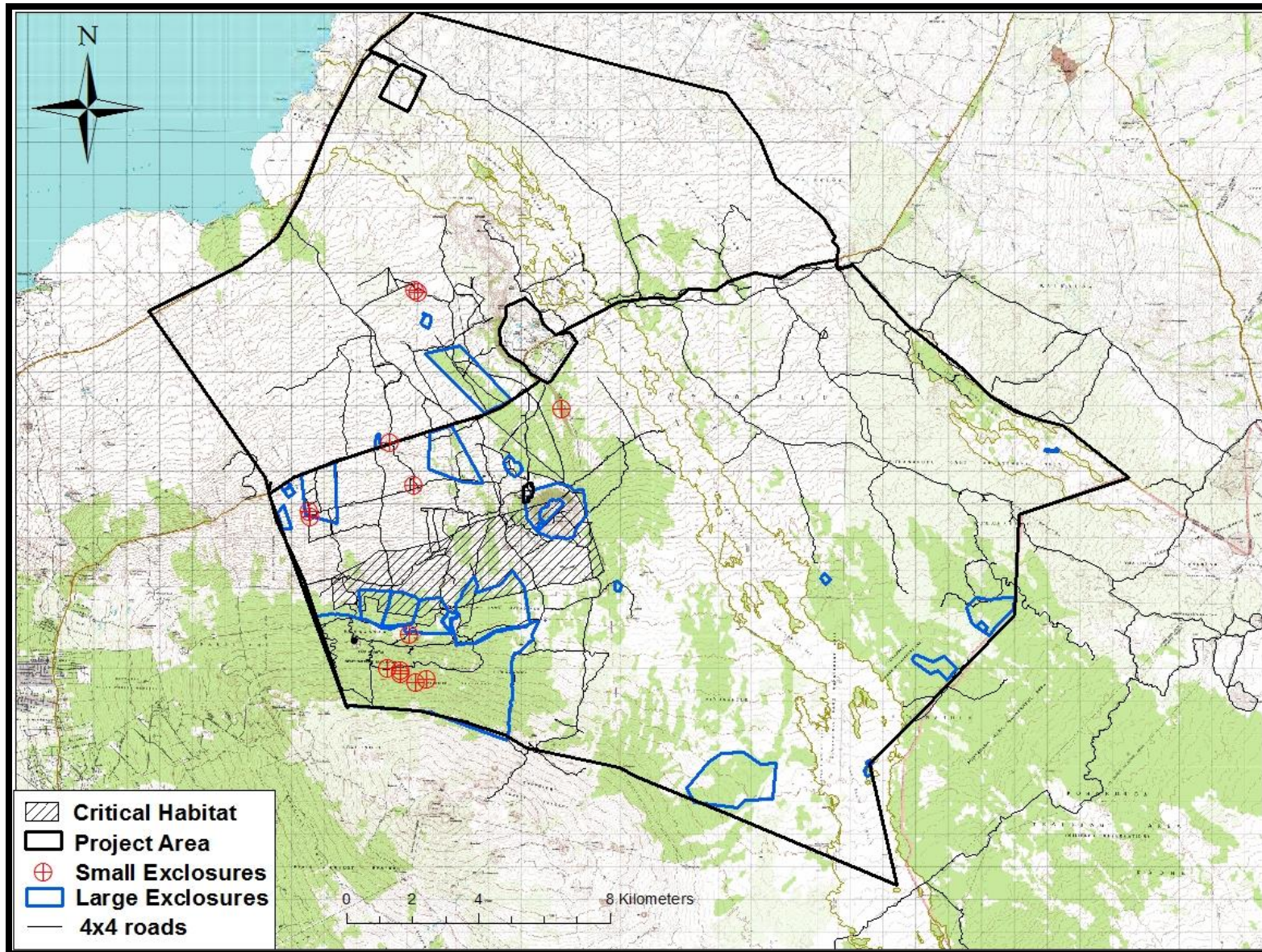


Figure 3.12 Critical habitat for A'e (*Zanthoxylum dipetalum* var. *tomentosum*) within the Plan Area.

3.5.4.15 A‘e (*Zanthoxylum hawaiiensis*)



Description: A medium-size tree 3 to 8 m tall, with a trunk 25 cm in diameter (Army 2010). The bark is pale to dark gray, and the leaves are lemon-scented. Alternate leaves are composed of three small leaflets, one being terminal and two lateral. The surfaces are usually without hairs, or the lower may be finely hairy and glandular. Fifteen to 20 flowers are arranged in open flower clusters, 4 to 8 cm long, which are subtended by main flower stalks 20 to 50 mm long. Each flower is subtended by a flower stalk, 2 to 4 mm. Usually, all flowers on a tree are of one sex, either male or female. A sickle-shaped, round-tipped fruit, 8 to 10 mm long, opens on one side to release one round, slightly compressed seed. The seed covering is pitted and sculptured, about 7 to 8 mm long, distinguished from other Hawaiian members of the genus by several characters: three leaflets all of similar size, one joint on a lateral leaf stalk, and sickle-shape fruits with a rounded tip (Army 2010).

Historic and Current Distribution: A‘e (*Z. hawaiiense*) is known from five main islands: Kaua‘i, Moloka‘i, Lāna‘i, Maui, and Hawai‘i. Populations were located in central Kaua‘i; eastern Moloka‘i; central Lāna‘i; southern and southwestern slopes of Haleakalā, Maui; and Kohala mountain, northern slopes of Hualālai, and the northwestern slope of Mauna Loa, Hawai‘i (Army 2010). On Kaua‘i, A‘e (*Z. hawaiiense*) was observed at Kawaiiki Ridge in 2013 and Koaia Canyon in 2012. There are two wild individuals on Kaua‘i. On Moloka‘i and Maui, this species is known from five or six populations totaling 14 individuals in 2008. On Moloka‘i, there are three mature individuals at Kamalo and Makolelau Gulch. On West Maui there are approximately 48 individuals and on East Maui there are three individuals (USFWS 2015d). See Table 3.5 for a summary table of species distribution state-wide.

On Hawai‘i Island, A‘e (*Z. hawaiiense*) are widely scattered within Pu‘u Wa‘awa‘a, Pu‘u Anahulu, and the Pōhakuloa Training Area. Pōhakuloa Training Area most recent surveys have indicated 650 individuals. Overall, the numbers of individuals have increased from the approximately 550 wild individuals reported in the previous five year review to approximately 916 wild individuals in 2015 (USFWS 2015d). During the HCP surveys 219 individuals were within the Plan Area.

Habitat: A‘e (*Z. hawaiiense*) occurs in lowland dry and mesic forests, and montane dry forest, at elevations between 550 and 1,740 m (Gagne and Cuddihy 1990, Army 2010). The taxon grows

in forests dominated by ‘Ōhi‘a, Lama, and Hala pepe. Other associated species include Hame (Kaua‘i), A‘ia‘i, Kōlea, Māmane, and Naio. Critical habitat was designated for this species in 2003; however CH does not occur within the Plan Area (USFWS 2003c).

Table 3.4 Species distribution, PEPP Status (PEPP: Less than 50 individuals remain in the wild, ROI: rare on island, AS: assumed stable, apparently secure, POP: potentially PEP species), and Federal Status (E: endangered, SOC: species of concern, C: candidate for listing) for species mapped during HCP botanical surveys.

Taxon	Common Name	Family	Distribution	PEP Status	Status
<i>Asplenium peruvianum</i> var. <i>insulare</i>		Aspleniaceae	Hawai‘i and Maui	none	E
<i>Mezoneuron kavaiense</i>	Uhiuhi	Fabaceae	Hawai‘i, Maui, Lāna‘i, O‘ahu, and Kaua‘i	ROI	E
<i>Colubrina oppositifolia</i>	Kauila	Rhamnaceae	Hawai‘i, Maui, and O‘ahu	AS	E
<i>Haplostachys haplostachya</i>	Honohono	Lamiaceae	Hawai‘i, Maui, and Kaua‘i	None	E
<i>Hibiscus brackenridgei</i> subsp. <i>brackenridgei</i>	Ma‘o hau hele	Malvaceae	Hawai‘i, Maui, and Lāna‘i	PEP	E
<i>Kokia drynarioides</i>	Koki‘o	Malvaceae	Hawai‘i	PEP	E
<i>Neraudia ovata</i>		Urticaceae	Hawai‘i	PEP	E
<i>Nothoecstrum breviflorum</i>	‘Aiea	Solanaceae	Hawai‘i	None	E
<i>Chrysodracon hawaiiensis</i>	Hala pepe	Asparagaceae	Hawai‘i	None	E
<i>Portulaca sclerocarpa</i>	Po‘e	Portulacaceae	Hawai‘i and Lāna‘i	PEP	E
<i>Silene lanceolata</i>	Hawaiian Catchfly	Caryophyllaceae	Hawai‘i, Lāna‘i, Moloka‘i, O‘ahu, Kaua‘i	None	E
<i>Solanum incompletum</i>	Pōpolo kū mai	Solanaceae	Hawai‘i, Maui, Lāna‘i, Moloka‘i, and Kaua‘i	POP	E
<i>Stenogyne angustifolia</i>		Lamiaceae	Hawai‘i, Maui, and Moloka‘i	None	E
<i>Zanthoxylum dipetalum</i> var. <i>tomentosum</i>	A‘e	Rutaceae	Hawai‘i	PEP	E
<i>Zanthoxylum hawaiiense</i>	A‘e	Rutaceae	Hawai‘i, Maui, Lāna‘i, Moloka‘i, and Kaua‘i	None	E
<i>Alphitonia ponderosa</i>	Kauila	Rhamnaceae	Hawai‘i, Maui, Lāna‘i, Moloka‘i, and Kaua‘i	None	SOC
<i>Eragrostis deflexa</i>		Poaceae	Hawai‘i, Maui, Lāna‘i, and Moloka‘i,	None	SOC

Taxon	Common Name	Family	Distribution	PEP Status	Status
<i>Erythrina sandwicensis</i>	Wiliwili	Fabaceae	All the main Hawaiian islands	None	SOC
<i>Euphorbia olowaluana</i>	‘Akoko	Euphorbiaceae	Hawai‘i and Maui	None	SOC
<i>Exocarpus gaudichaudii</i>	Hulumoa	Santalaceae	All the main Hawaiian islands except Kaua‘i	None	SOC
<i>Fragaria chiloensis</i>	‘Ōhelo papa	Rosaceae	Hawai‘i and Maui	None	SOC
<i>Melicope hawaiiensis</i>	Manena	Rutaceae	Hawai‘i, Maui, Lāna‘i, and Moloka‘i,	None	SOC
<i>Polyscias sandwicensis</i>	‘Ohe makai	Araliaceae	Ni‘ihau, Hawai‘i, Lāna‘i, Moloka‘i, O‘ahu, Kaua‘i	None	SOC
<i>Sisyrinchium acre</i>	Mau‘u lā‘ili	Iradaceae	Hawai‘i and Maui	None	SOC
<i>Stenogyne macrantha</i>		Lamiaceae	Hawai‘i	None	SOC
<i>Tetramolopium consanguineum</i>		Asteraceae	Hawai‘i and Kaua‘i	None	SOC
<i>Tetramolopium humile</i>		Asteraceae	Hawai‘i and Maui	None	SOC

Table 3.5 Number of individuals of Covered Species in the Plan Area and across the state. A population is defined as a group of individuals within 1000m of one another. Values for number of individuals across the state come from the most recent USFWS 5 year review and summary evaluation reports for each of the covered Species.

Species	Known Individuals in Plan Area	Populations in Plan Area	State wide	O‘ahu	Hawai‘i	Maui	Kaua‘i	Lāna‘i	Moloka‘i
<i>Asplenium peruvianum</i> var. <i>insulare</i>	64	3	948		931	17			
<i>Chrysodracon hawaiiensis</i>	299	5	400		400				
<i>Colubrina oppositifolia</i>	739	1	1265	54	1209	2			
<i>Haplostachys haplostachya</i>	80	1	10,000		10,000	X	X		
<i>Hibiscus brackenridgei</i> subsp. <i>brackenridgei</i>	65	1	76		9	63		4	
<i>Kokia drynarioides</i>	4	1	2		2				
<i>Mezoneuron kavaiense</i>	48	1	99	4	94	X	1	X	
<i>Neraudia ovata</i>	9	2	90		90				
<i>Nothoestrum breviflorum</i>	156	3	150		150				
<i>Portulacca sclerocarpa</i>	1	1	200		200			X	
<i>Silene lanceolata</i>	235	3	20,000	189	10,394		X		622
<i>Solanum incompletum</i>	13	1	86		86	X	X	X	X
<i>Stenogyne angustifolia</i>	98	3	5000		5,000	X			X
<i>Zanthoxylum dipetalum</i> var. <i>tomentosum</i>	13	2	13		13				
<i>Zanthoxylum hawaiiense</i>	219	2	916		860	51	2	X	3

3.5.5 Plant Species of Concern

Plant SOC were also documented during HCP surveys (Table 3.6). While these species are not ‘Covered Species’ for the purposes of licensing; exclosures and outplanting of SOC will benefit Covered Species by creating a more diverse plant assemblage that will improve ecosystem function. SOC species will be outplanted in exclosures along with appropriate common native species to increase species diversity, provide synergistic and functional gains between species, and benefit native species. Additions of these species will provide additional net environmental benefit, and will assist in the restoration of degraded natural communities within the Plan Area.

Table 3.6 Documented flora SOC in the Plan Area. These species will potentially benefit from existing and planned exclosures. Existing and outplanted individuals of these species will be included in HCP protection and restoration, to the extent feasible and appropriate.

Scientific Name	Common Name
<i>Alphitonia ponderosa</i>	Kauila
<i>Euphorbia olowaluana</i>	‘Akoko
<i>Eragrostis deflexa</i>	Love Grass
<i>Erythrina sandwicensis</i>	Wiliwili
<i>Exocarpus gaudichaudii</i>	Hulumoa
<i>Fragaria chiloensis</i>	‘Ōhelo papa
<i>Melicope hawaiiensis</i>	Manena
<i>Polyscias sandwicensis</i>	‘Ohe Makai
<i>Sisyrinchium acre</i>	Mau‘u lā‘ili
<i>Stenogyne macrantha</i>	
<i>Tetramolopium consanguineum</i>	
<i>Tetramolopium humile</i>	

3.6 WILDLIFE

3.6.1 Covered Species

3.6.1.1 Blackburn’s Sphinx Moth (*Manduca blackburni*)



Background: (Adapted from the USFWS Draft Recovery Plan for the Blackburn’s sphinx moth, 2003) The Blackburn’s sphinx moth (*Manduca blackburni*, BSM) is one of Hawai‘i’s largest native insects, with a wingspan of up to 12 centimeters and is one of four federally listed insects in the State of Hawai‘i (USFWS 2003b). Like other sphinx moths in the family Sphingidae, it has long, narrow forewings, and a thick, spindle-shaped body tapered at both ends. It is grayish brown in color, with black bands across the apical (top) margins of the hind wings, and five orange spots along each side of the abdomen. The larva is a typical, large “hornworm” caterpillar, with a spine-like process on the dorsal surface of the eighth abdominal segment. Although the moth probably occurred on the islands of Kaua‘i, Kaho‘olawe, O‘ahu, Moloka‘i, Maui, and Hawai‘i, extant populations are now limited to Maui, Kaho‘olawe, and Hawai‘i. On Hawai‘i, it was known from Hilo, Pāhala, Kalaoa, Kona, and Hāmākua. They have been observed from sea level to 1,525 meters elevation. *Manduca blackburni* is designated as an endangered species under federal and state laws.

Manduca blackburni larvae feed on plants in the nightshade family (Solanaceae). The native host plants are trees within the genus *Nothocestrum* (‘Aiea), on which the larvae consume leaves, stems, flowers, and buds. However, many of the host plants recorded for this species are not native to the Hawaiian Islands, and include commercial tobacco (*Nicotiana tabacum*), tree tobacco (*Nicotiana glauca*), eggplant (*Solanum melongena*), tomato (*Lycopersicon esculentum*), and Jimson weed (*Datura stramonium*) (Hobdy 2014).

Little is known from direct observation of this species, as it was unobserved and considered extinct until it was rediscovered on Maui in 1984. In general, sphingid moths can develop from egg to adult in as little as 56 days, but pupae may remain in a state of torpor (inactivity) in the soil for up to a year. Adult sphingid moths have been found throughout the year and are known to feed on nectar from a variety of host plants. Sphingids generally live longer than most moths because of their ability to feed and take in water from a variety of sources, rather than relying only upon stored fat reserves.

Because they live longer, female sphingid moths will often take more time in locating the best host plants for egg laying (Kitching and Cadiou 2000), relative to other moth species.

Two field observations of feeding *M. blackburni* adults have been made, one within the Kanaio Beach area of southeast Maui, where adults were documented to be feeding upon the nectar of the native Hawaiian morning glory species, *Ipomoea indica*. The second observation was made in the upper Kanaio NAR, where a single adult was found feeding upon the nectar of *I. indica*. It is expected the native Hawaiian species of caper, *Capparis sandwichiana* and *Plumbago zeylanica* are also likely native adult *M. blackburni* food sources. All three species, *C. sandwichiana*, *P. zeylanica*, and *I. indica* bear flowers that share some traits suggestive of moth pollination, including nocturnal anthesis (opening at night), light coloration, and/or the emittance of strong fragrances (*C. sandwichiana*) upon opening.

Previous *M. blackburni* larvae sightings have been documented between the months of October and May, but more recent observations in the Plan Area confirm larval presence on tree tobacco in July, August, and September. Adult moths are found throughout the year. Recent light trapping surveys indicate that the species does occur in the Plan Area, with larvae predominantly occurring on tree tobacco in areas of high disturbance such as near fuelbreaks and roadsides and in areas previously burned by wildfires. Future surveys for larvae on ‘Aiea are necessary to establish distribution and density on the native host plant. The limited data collected to date suggests that the species has a moderate to wide distribution in the Plan Area, and that potential impacts to the species should be considered and, if significant, avoided, minimized, and mitigated.

***M. blackburni* critical habitat designation**

Critical habitat is the term used to define those areas of habitat containing physical and biological features that are essential for an endangered or threatened species to recover and that require special management or protection. In July of 2003, the USFWS designated a total of about 55,000 acres of critical habitat for the Blackburn’s sphinx moth. Approximately 25,000 acres of this designated critical habitat occur within the Plan Area, specifically within Pu‘u Wa‘awa‘a Forest Reserve (Figure 3.13). Critical habitat designation requires the Service to consult under section 7 of the ESA with regard to actions carried out, funded, or authorized by a federal agency when those actions may harm endangered species, or modify critical habitat. Four wheel drive roads and fuel breaks are not included in the critical habitat designation because they were existing man-made features when critical habitat was designated (USFWS 2003c). A section 7 consultation for federally funded road and fuelbreak clearing activities with an approved Biological Opinion was finalized in October 2015 (USFWS 2015e).

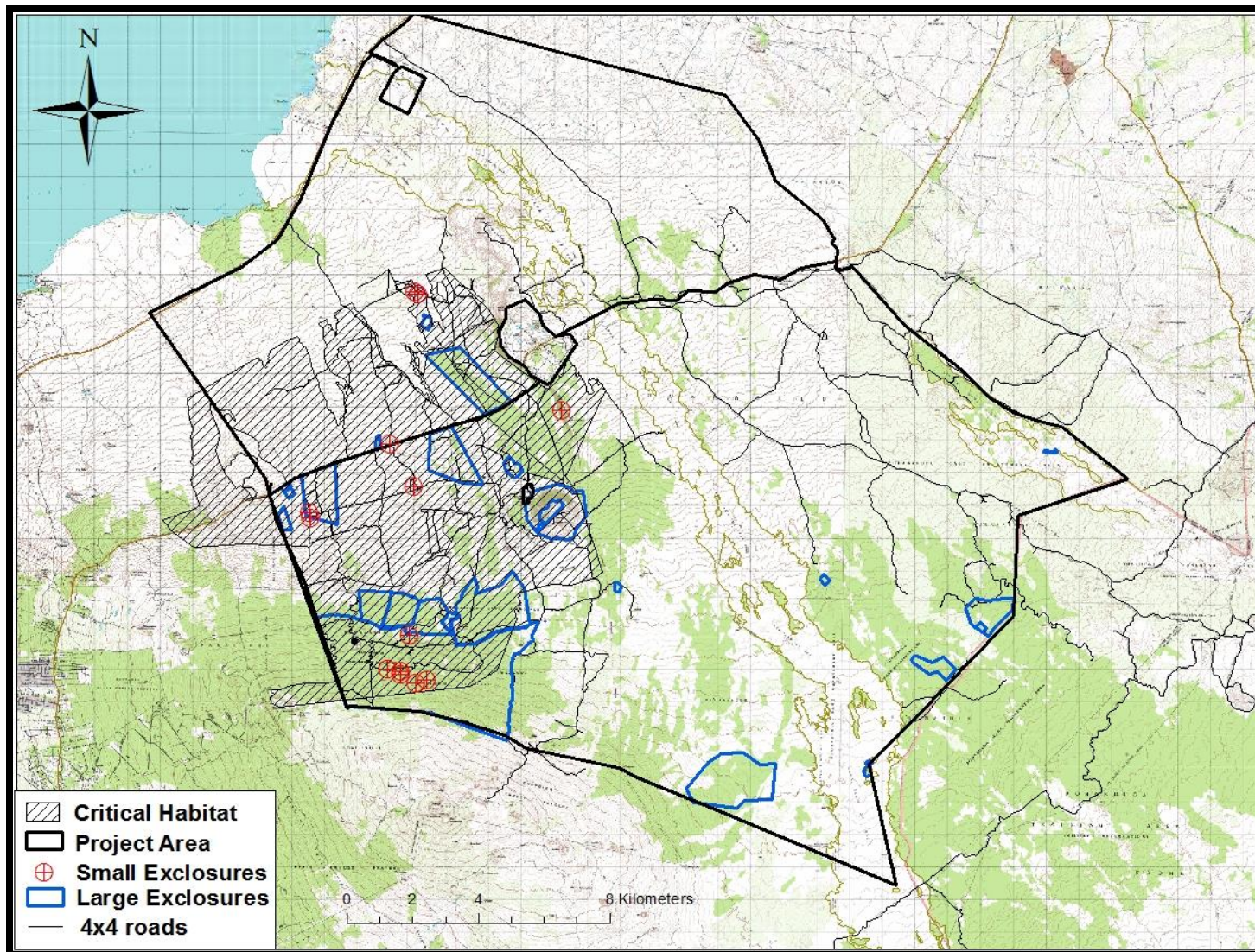


Figure 3.13 Blackburn's sphinx moth critical habitat within the Plan Area.

***M. blackburni* within the Plan Area**

Blackburn's sphinx moth has been identified as being potentially impacted through the maintenance and creation of fuelbreaks and four-wheel drive access roads. There is no expected take of adult *M. blackburni* due to fuelbreak and road maintenance. However, take of eggs, larvae, and pupae may occur due to road clearing activities that remove host plants, specifically, tree tobacco. While take can be avoided and minimized through flexible clearing schedules, some take is anticipated and will be covered under this HCP.

Within the Plan Area, *M. blackburni* larvae have been observed on both native plants ('Aiea), and non-native plants (tree tobacco). The HCP botanical surveys documented the location and distribution of 'Aiea within the Plan Area. Because the botanical surveys did not cover 100% of all land within the Plan Area due to financial, logistical, and staff constraints, modeling was used to determine the number of 'Aiea that may have been missed (*See Modeling and Estimated Take section 5.3 for more details*).

In January 2010, HCP staff began documenting the distribution of tree tobacco that occurs on roadsides and fuelbreaks within the Plan Area by recording plant locations using Global Positioning System (GPS) technology as HCP staff drove 4x4 roads. For each location, a general description of the number of plants (limited to those occurring along roadsides) in that given area was recorded (*For more information see Section 5.3.6*).

To quantify the distribution and density of Blackburn's sphinx moth eggs and larvae, DOFAW conducted surveys at random locations throughout the Plan Area. Surveys were conducted to quantify egg and larval densities both on roadside (2011 and 2012) and off of the road (2012), and to quantify characteristics of tree tobacco that might be important to adult moths when selecting host plants. We considered three individual plant characteristics that we hypothesized might influence the distribution and abundance of eggs and larvae; tree leaf density, tree height, and tree location (on-road or offroads). Tree tobacco leaf density and height vary greatly across the landscape from small developing plants with few large leaves to larger (3-5 m tall) trees with numerous smaller and tougher leaves. Tree density also varied across the landscape with the vast majority of individual trees and stems occurring on or directly adjacent to road-sides. We hypothesized that higher abundance of eggs and larvae would be found on shorter (younger) trees with larger leaves (because of both larger available surface area and higher quality food for larvae), and also on roadsides (as compared to off-road) because roadside trees tended to be smaller and have larger leaves and higher densities of trees. When tree tobacco is damaged (due to road clearing, tires, etc.), roots will often send out new shoots with large leaves.

The surveys indicated that while a smaller proportion of trees fall in to the high leaf density category (as compared to the low and medium leaf density categories), a higher proportion of eggs and larvae can be found on trees with high leaf density, suggesting the adult moths are preferentially selecting this category. Survey data also indicated a greater proportion of tree use with increasing tree height; specifically, moths appeared to be preferentially selecting trees of a larger size, in particular those in the 2-5 m height class. Moreover, only 2% of detected larvae were found on trees less than one meter tall. Surveys were conducted on roads as well as in off-road areas perpendicular to roadsides

to see if roads themselves are something important for host site selection. We found that approximately the same proportions of trees of each category are being used by Blackburn's sphinx moth on roadsides as compared to off road areas in relation to what is available for use on the landscape. This indicates that roads do not have a measurable impact on host site selection, and that the other factors surveyed (i.e. leaf density and tree height) may be more important to Blackburn's sphinx moth (*See Appendix D, section 11.0 for detailed information on surveys and results*).

3.6.2 Non-Covered Species

3.6.2.1 Vertebrate and Invertebrate Species

Appendix B includes a list of the endangered, threatened, and candidate vertebrate and invertebrate species that are known to occur within the Plan Area. Potential impacts to each of these protected species have been considered. Protected animal species with no expected take due to Plan activities are listed in this section.

Nēnē (*Branta sandvicensis*)

Nēnē, or Hawaiian geese, are known to prefer open short grassland habitats and fresh greens, and are not dependent for food or habitat upon any of the plant species covered under this HCP. No known Nēnē habitat, nesting area, or Nēnē themselves will be disturbed or destroyed by Plan actions. Nēnē will benefit from increased natural forage in protected areas. No direct or indirect take is anticipated; Nēnē will be provided net benefit due to HCP implementation.

‘Io (*Buteo solitaries*)

‘Io, or Hawaiian hawk, is found in a wide variety of habitats, from exotic forest and pastureland in the lowlands to native forest as high as 2,712 m in elevation. No ‘Io or their nesting areas will be disturbed or destroyed by Plan actions. ‘Io may benefit somewhat from an increase in nesting and roosting sites, after mature vegetation has developed in protected areas, relative to the extant fountain grass dominated landscape. No direct or indirect take is anticipated; ‘Io will be provided net benefit due to HCP implementation.

Honu (*Chelonia mydas*)

No Plan activities occur in the beach area potentially accessed by Honu (green sea turtles). Plan activities will not affect marine or coastal environments. No take is anticipated for Honu.

Ae‘o (*Himantopus mexicanus knudseni*)

The Ae‘o, or Hawaiian stilt, is known to nest in the 49 acre Hauaina fenced unit near a man made reservoir. As this enclosure is already in place, no take is anticipated for this species.

‘Ōpe‘ape‘a (*Lasiurus cinereus semotus*)

‘Ōpe‘ape‘a, or Hawaiian hoary bat, are known to use the Plan Area for foraging and probably for nesting. Bats can be seen nightly foraging in the vicinity of the Hauaina unit. These bats are flexible in their roosting and foraging areas, and utilize a wide variety of trees, including both native and non-native tree species for roosting, and native and non-native invertebrate species as prey. The current Plan includes no tree removal which could potentially impact ‘Ōpe‘ape‘a. Increases in native tree cover, and increases in native species diversity should result in a net gain in roosting and possibly foraging opportunities, particularly in areas currently dominated by fountain grass, as trees in enclosures become more established. No direct or indirect take of bats is anticipated. ‘Ōpe‘ape‘a, will be provided net benefit by Plan activities.

Hawai‘i ‘Akepa (*Loxops coccineus coccineus*) and Hawai‘i creeper (*Oreomystis mana*)

Both the Hawai‘i ‘Akepa and Hawai‘i creeper are known to occur or have occurred within the fenced Pu‘u Wa‘awa‘a Forest Bird Sanctuary, which is already fenced. Habitat loss is listed as the greatest threat to these birds, and both species are expected to gain habitat, nesting and foraging opportunities through Plan actions, resulting in a net benefit to these endangered species. No direct or indirect take from Plan activities is anticipated. These and other forest bird species will receive net benefits from HCP activities, particularly as forests within the exclosures become more established.

Drosophila heteroneura

A member of the picture wing family, this drosophilid fly inhabits rain forest communities, and is closely associated with *Cheirodendron* bark, *Clermontia* bark, and *Delissea* stem (Montgomery 1975). No negative effect is expected on the associated host plants; therefore no direct or indirect take is anticipated for this species. It is possible that the flies will benefit from an increase in natural communities in the Plan Area, an additional Plan benefit.

4.0 BIOLOGICAL GOALS AND OBJECTIVES

DOFAW has worked to assess the potential for the proposed Covered Activities to cause adverse effects to the Covered Species. The purpose of identifying these goals and objectives is to establish a framework for developing the conservation measures for the HCP; we are using the USFWS Five-point Policy as guidance for the HCP process (USFWS 2000).

4.1 GOALS

Biological goals are intended to be broad, guiding principles that clarify the purpose and direction of the HCP (USFWS 2000). The biological goal for this HCP is to secure and maintain the survival of native plant and animal species that occur within the Plan Area through restoration activities aimed at maintenance and enhancement of essential habitat and community function.

The specific goals of this HCP are to:

- Avoid, minimize, and mitigate the potential effects of the Covered Activities on the Covered Species associated with game mammal management and maintenance activities of the Plan;
- Increase the knowledge and understanding of the occurrence and distribution of the Covered Species in the Plan Area;
- Adhere to the goals of the recovery plans for each of the Covered Species; and
- Provide a net conservation benefit to each of the Covered Species.

4.2 OBJECTIVES

The biological objectives for achieving the HCP goals are:

- Offset the potential direct and/or indirect effects of the Plan on the 15 Covered Plant Species through protection and maintenance of a minimum of at least three populations of each covered plant species with a total number of individuals equaling the take estimate or at least the minimum number of individuals required for stabilization (whichever value is greater) as put forth by the recovery plans for each Covered Species. As well as propagate additional populations of the 15 Covered Plant species as needed to provide net environmental benefit, ensure genetic representation, and increase the likelihood of recovery.
- Provide protection for existing *in situ* populations of Covered Plant Species through maintaining or constructing exclosures. These management units or exclosures of various sizes will be managed for multi-species benefit to provide natural community function, whenever feasible.
- Offset the potential direct and indirect effects of the Plan on Blackburn's sphinx moth during road and fuelbreak maintenance through pre-maintenance avoidance measures and by outplanting and protecting native host plants and nectar plants.
- Provide adequate monitoring for each of the impacted Covered Species, including but not limited to population monitoring, monitoring measures of success, ongoing take, and net benefit.

- Provide periodic reports, review, assess, and implement appropriate adaptive management measures as needed.

4.3 AVOIDANCE AND MINIMIZATION MEASURES

Section 195D-21 of the Hawai‘i Revised Statutes requires that an HCP describe the steps that will be taken to avoid, minimize and mitigate the effects of the taking provided for in the plan, and that, for an HCP to be approved, such taking be minimized and mitigated to the maximum extent practicable where complete avoidance is not possible. The DLNR will take appropriate steps to avoid adverse effects to the Covered Species. DLNR has incorporated measures, identified below, to avoid and minimize take of the Covered Species.

4.3.1 General Plan Development Measures

The spread of invasive, non-native plant species caused by fence construction will be minimized through cleaning and inspecting equipment coming to the site and maintenance of fuelbreaks (weed-free buffers) around all fenced units. Any areas within fenced units that are disturbed by fencing activities will be replanted with native species (*see Appendix B for a list of potential outplanting species*). Trash, especially food stuffs, will be removed from the construction area on a weekly basis to avoid attraction of ants and other animals such as mongooses, cats, and rats that may negatively affect the Covered Species.

A biologist will be on staff during fencing operations to conduct post-fence construction monitoring surveys, to assist with mitigation measures, and to address any potential wildlife and botanical issues that may arise.

4.3.2 Pre-Road Clearing Surveys and Timing Considerations

To minimize impacts to Blackburn’s sphinx moth habitat, all known ‘Aiea (the native host plant) within the Plan Area will be permanently protected from ungulates.

Blackburn’s sphinx moth larvae have been documented on tree tobacco year round with highest numbers found from December to March. Surveys have shown that larvae primarily use trees larger than one meter in height (*See Appendix D for survey results*). To minimize impacts to Blackburn’s sphinx moth, intensive control or removal of tree tobacco along roadsides and fuelbreaks will be done when larvae are known to be less abundant, from June through August. After intensive summer clearing, roads may be cleared every two months to maintain access and keep the fuelbreaks free of vegetation. By maintaining a consistent road clearing schedule, take of larvae and eggs will be minimized as trees cleared will primarily be less than one meter in height (*see section 3.6.1*). For a detailed description of methods used for clearing roads and breaks, please see section 5.2.2.

4.3.3 Invasive Plant Species Management

DLNR will work actively to minimize and reduce the ingress of additional undesirable invasive plant species into the Plan Area. DLNR intends to implement measures to minimize and avoid the introduction of invasive species to the Plan Area including:

All equipment, materials, and vehicles brought onto the site during fence construction will be cleaned and inspected to prevent the introduction of invasive or harmful non-native species. An inspection station will be located at a staging area designated prior to construction (staging area location may change based on location of contracted work).

To minimize the introduction and spread of invasive plant species, potential off-site sources of materials (e.g., fence materials) will be inspected, and the import of materials from sites that are known or likely to contain seeds or propagules of particularly harmful invasive species will be prohibited.

Vehicle operators transporting materials to the proposed Plan site from off site will be required to follow protocols for removing soils and plant material from vehicles and equipment prior to entry onto the site.

The goal within conservation units is to control 90% of invasive species (primarily fountain grass and kikuyu grass¹⁴) from within three meters of an individual (or cluster of) Covered Species and, maintain a 25-50 m buffer of less than 50% invasive grass coverage around an individual (or cluster of) Covered Species.

Tree tobacco within exclosures will be surveyed for Blackburn's sphinx moth eggs and larvae prior to tree removal. Unoccupied tree tobacco plants will be removed to prevent future use by the Blackburn's sphinx moth. Plants less than one meter tall will be removed by pulling, while plants greater than one meter tall will be cut and treated with herbicide. Should any larvae be found just prior to plant removal or cutting, the larvae will be removed and relocated by trained, authorized staff to a nearby location outside the area of disturbance that contains suitable moth habitat to avoid direct take.

4.3.4 Rapid Ōhi'a Death Prevention

A newly identified disease has killed large numbers of mature 'Ōhi'a trees in forests and residential areas of the Puna and Hilo Districts of Hawai'i Island. Landowners have observed that when previously healthy-looking trees begin to exhibit symptoms they typically die within a matter of weeks. Pathogenicity tests conducted by the USDA Agriculture Research Service have determined that the causal agent of the disease is the vascular wilt fungus, *Ceratocystis fimbriata* (Keith et al. 2015). This disease has the potential to kill 'Ōhi'a trees statewide. The disease affects non-contiguous forest stands ranging from 1 to 100 acres. As of 2014, approximately 6,000 acres from Kalapana to Hilo on Hawai'i Island had been affected with stand showing greater than 50% mortality. The disease has not yet been reported on any of the other Hawaiian Islands.

As of early 2015 the disease was confined to Hilo and the Puna district on Hawai'i Island. Currently, there is no effective treatment to protect 'Ōhi'a trees from becoming infected with *Ceratocystis* or cure trees that exhibit symptoms of the disease. To reduce the spread of *Ceratocystis*, landowners should not transport wood of affected 'Ōhi'a trees

¹⁴ Fountain and kikuyu grass have been identified as the most damaging invasive plant species in the Plan Area. Additional weed species will be controlled on a case by case basis. Some alien species, such as kikuyu grass can hinder the encroachment of more aggressive weed species allowing for better outplanting conditions and can be left in place until outplants are near ready to be planted.

to other areas. The pathogen may remain viable for over a year in dead wood. Tools used for cutting infected ‘Ōhi‘a trees should be cleaned either with Lysol™ or a 70% rubbing alcohol solution. A freshly prepared 10% solution of chlorine bleach and water can be used as long as tools are oiled afterwards, as chlorine bleach will corrode metal tools. Chain saw blades should be brushed clean, sprayed with cleaning solution, and run briefly to lubricate the chain. Vehicles used off-road in infected forest areas should be thoroughly cleaned underneath so as not to carry contaminated soil to healthy forests. Shoes, tools, and clothing used in infected forests should also be cleaned, especially before being used in healthy forests.

4.3.5 Ignition Prevention

Hot catalytic converters, exhaust systems, sparks, cigarettes, and other ignition sources may be present while staff and the public access the Plan Area. Proper ignition prevention procedures will be followed by all workers. Vehicles will not be parked in vegetation of any kind whenever possible. In some locations this may not be feasible. In these locales, vehicles will not park in vegetation greater than 10 cm in height. Smokers shall field strip their cigarettes immediately after smoking (remove tobacco from the butt and scatter it, ensuring that the tobacco is not lit), and properly dispose of cigarettes inside their vehicle.

4.3.6 Ungulate Proof Enclosures

Ungulate-proof enclosures are the most effective tool for minimizing impacts associated with ungulate grazing and browsing, and vehicular and foot traffic. The enclosures will be constructed based on the locality of the endangered plant species, feasibility, and effectiveness. Enclosure fences will be constructed with 6-foot woven hog-wire fencing secured by 8-foot tall T-posts. No barbed wire will be used to avoid entanglement to wildlife. Fences will be skirted with additional hog-wire or deer fence to prohibit burrowing. Fencing personnel and materials will access to the site along existing access roads by vehicle or by helicopter.

4.3.6.1 Fencing Unit Priority¹⁵

The first phase of implementation will focus on avoidance and minimization of take through the installation of fencing units. Fencing priority is listed below in Table 4.1. This priority is based on the number of known *in situ* plant populations present within the unit as well as PEPP (Plant Extinction Prevention Program) status, and overall number of populations within the Plan Area.

¹⁵ Priority is subject to change based on availability of funding.

Table 4.1 Fencing priority for fencing units within the Plan Area. Type: A/M= avoidance and minimization and Mit= mitigation. Species codes are: AspPer = *Asplenium peruvianum*, ChrHaw = *Chrysodracon hawaiiensis*, ColOpp = *Colubrina oppositifolia*, HapHap = *Haplostachys haplostachya*, HibBra = *Hibiscus brackenridgei*, KokDry = *Kokia drynarioides*, MezKav = *Mezoneuron kavaense*, NerOva = *Neraudia ovata*, NotBre = *Nothoestrum breviflorum*, SilLan = *Silene lanceolata*, SolInc = *Solanum incompletum*, ZanDip = *Zanthoxylum dipetalum*, ZanHaw = *Zanthoxylum hawaiiensis*

Fencing Unit	Type	Size ¹⁶ (acres)	Rationale
Henahena	A/M	731	NotBre avoidance of take
Hala pepe	A/M	92	ChrHaw avoidance of take
‘Aiea	A/M	291	NotBre avoidance of take
Honohono	A/M	5	Only known population on State land and PEPP species
Solanum Kīpuka	A/M	18	Only known population on State land and PEPP species
Kauila Hala pepe	A/M	375	Avoidance of take of ColOpp and ChrHaw
Zanthoxylum II	A/M	815	Avoidance of take of ZanHaw
Anahulu I	A/M	255	Avoidance of take for NerOva, ZanHaw, SilLan, SteAng
Anahulu II	A/M	124	Avoidance of take for ZanHaw and NerOva
Stenogyne	A/M	10	Avoidance of take for SteAng
Uhiuhi 4	A/M	22	Avoidance of take for MezKav
Pu‘u Loa	A/M	530	Avoidance of take for ChrHaw, MezKav, ColOpp
PWW CCA (remaining units)	Mit	330	Mitigation for 13 of 15 Cover Species

¹⁶ Exclosure size and exact location may vary depending on Covered plant locations, geography, roads, access, and surrounding exclosures. Exclosure size is based on GIS acres.

Fencing Unit	Type	Size¹⁶(acres)	Rationale
South Kīpuka	Mit	42	Outplanting site for lowland dry forest species (sites lacking)
Waihou II	Mit	202	Outplanting site for multiple Covered Species
Lama w/ Koki‘o	Mit	382	Last known KokDry at PWW. Avoidance of take for ColOpp, NotBre, ChrHaw.
Kileo	Mit	533	Outplanting site for AspPer, HapHap, NerOva, NotBre, PorScl, SilLan, SolInc, SteAng, and ZanHaw.
Total Proposed Mitigation Acreage		1,489	1.4% of the Plan Area
Total Proposed Avoidance/Minimization Acreage		3,268	3.1% of the Plan Area
Total Proposed Fenced Acreage¹⁷		4,757	4.5% of the Plan Area

¹⁷ Enclosure size and exact location may vary depending on Covered plant locations, geography, roads, access, and surrounding enclosures.

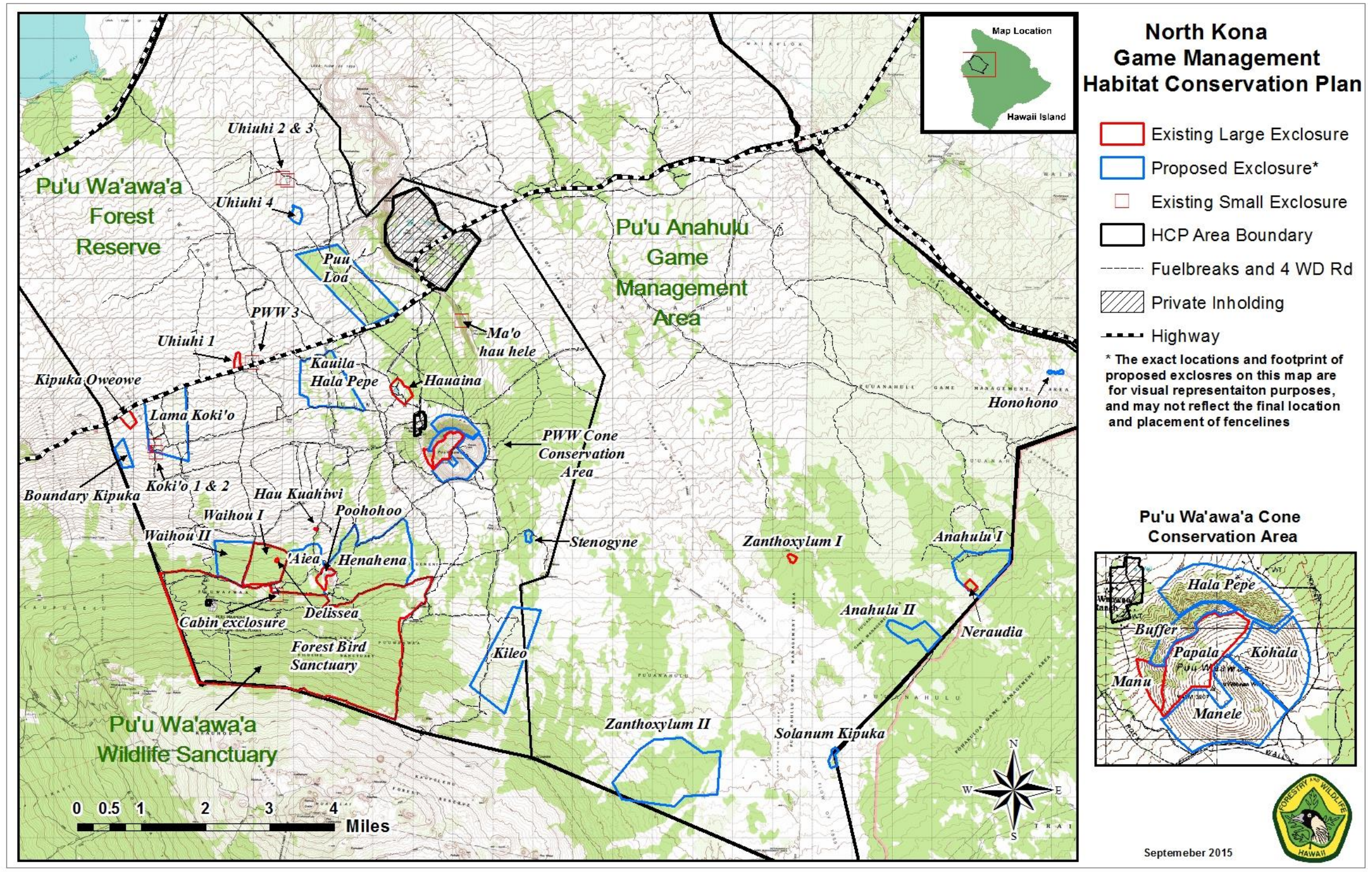


Figure 4.1 Current and proposed exclosures in the Plan Area.

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4.3.6.2 Proposed Enclosures

The proposed enclosures were designed based on the following approach:

- To provide for the protection of the plant species included in the incidental take license.
- To avoid negative effects of game mammal management on Covered Species.
- To promote functional native dominated communities. The construction of large enclosures is intended to protect a larger and more diverse native plant community.
- Use of existing fences and enclosures, whenever feasible and effective for plant protection, is preferred over building new fences, both to minimize cost and to minimize effects on game mammal management.

Henahena – 731 acres

This area is also known historically as Henehene (Fujii 1995) and contains predominantly ‘Ōhi‘a forest. This area also contains numerous sandalwood trees (‘Iliahi) and ‘Aiea which are hosts for the endangered Blackburn’s sphinx moth. Fencing of this area will protect remaining ‘Ōhi‘a forest stands and the fragile lava tube ecosystems that occur underneath this forest type by preventing animals from damaging vegetation over the lava tube ecosystem.

Pu‘u Wa‘awa‘a Cone Conservation Area (4 remaining units totaling 330 acres)

- Buffer: 29 acres: This unit will be used for mitigation for 12 Covered species.
- Mānele: 121 acres: This unit will be used for mitigation for 12 Covered species.
- Kōhala: 88 acres: This unit will be used for mitigation for 12 Covered species.
- Hala pepe: 92 acres: This unit contains a large concentration of Hala pepe and one individual A‘e (*Zanthoxylum dipetalum* var. *tomentosum*).

‘Aiea – 291 acres

This unit will incorporate a small concentration of the endangered ‘Aiea that is also important habitat for the endangered Blackburn’s sphinx moth. The forest here is dominated by ‘Ōhi‘a, Koa, Māmane, and Naio and contains scattered individuals of the endangered ‘Aiea, and the SOC ‘Akoko.

Honohono – 5 acres

This area contains the last known population of Honohono found on state land.

Solanum Kīpuka – 18 acres

Currently 8 individual fences occur in this kīpuka enclosing approximately nine Pōpolo kū mai plants. The entire kīpuka will be enclosed to further protect these remaining plants. The PTA boundary fence could be used as one side of the fence unit.

Kauila Hala pepe – 368 acres

This unit contains a large population of Kauila and Hala pepe.

Zanthoxylum II – 815 acres

This area contains the highest concentration and largest population of A‘e (*Z. hawaiiensis*) in the area.

Anahulu I – 255 acres

This area contains some of the best remaining dry forest shrubland in the upper Pu‘u Anahulu region. Pu‘u Anahulu has been plagued by fires in recent years resulting in a drastically altered landscape. Without management actions including fencing to protect plants from ungulates, fire control, and invasive species management, this area will likely burn in the future resulting in the loss of many species including: A‘e (*Z. hawaiiensis*), Hawaiian Catchfly, *Neraudia ovata*, and *S. angustifolia*.

Anahulu II – 124 acres

This area contains some of the best remaining dry forest shrubland in the upper Pu‘u Anahulu region. Pu‘u Anahulu has been plagued by fires in recent years resulting in a drastically altered landscape. Without management actions including fencing to protect plants from ungulates, fire control, and invasive species management, this area will likely burn in the future resulting in the loss of many species including: A‘e (*Z. hawaiiensis*), Hawaiian Catchfly, *Neraudia ovata*, and *S. angustifolia*.

Stenogyne – 12 acres

This area contains some of the highest concentration of *S. angustifolia* in the Plan Area. The site is also suitable for the potential reintroduction of Hawaiian Catchfly, *Neraudia ovata*, and ‘Aiea.

Uhiuhi 4 – 22 acres

This unit will protect nine Uhiuhi trees on the makai side of Pu‘u Wa‘awa‘a.

Pu‘u Loa – 530 acres

This large unit makai of the highway contains individuals of Kauila, Hala pepe, and Uhiuhi.

Boundary Kīpuka – 42 acres

This unit is primarily a mitigation unit for lowland dry forest species but may also contain ‘Aiea and Hala pepe.

Waihou II – 202 acres

The expansion of the Waihou forest fence will greatly increase the amount of protected area in which to recover both existing and recently extirpated endangered plant populations. This area contains numerous individuals of the endangered ‘Aiea which are host to the endangered Blackburn’s sphinx moth, at least two individuals of A‘e (*Z. dipetalum* var. *tomentosum*) and the SOC, ‘Akoko.

Lama Koki‘o – 382 acres

This unit is primarily a mitigation unit for lowland dry forest species and also contains ‘Aiea and Hala pepe.

Kileo – 533 acres

This unit is a mitigation unit for *A. peruvianum*, Honohono, *Neraudia ovata*, ‘Aiea, Po‘e, *Silene lanceolata*, Pōpolo kū mai, creeping mint, and A‘e (*Z. hawaiiense*).

Table 4.2 *In situ* individuals within exclosures. This table summarizes the presence of extant wild (*in situ*) individuals within proposed and current exclosures to be used for avoidance and minimization. Numeric values indicate the number of individuals of each species within each unit. Species codes are: AspPer = *Asplenium peruvianum*, ChrHaw = *Chrysodracon hawaiiensis*, ColOpp = *Colubrina oppositifolia*, HapHap = *Haplostachys haplostachya*, HibBra = *Hibiscus brackenridgei*, KokDry = *Kokio drynarioides*, MezKav = *Mezoneuron kavaiense*, NerOva = *Neraudia ovata*, NotBre = *Nothocestrum breviflorum*, SilLan = *Silene lanceolata*, SolInc = *Solanum incompletum*, ZanDip = *Zanthoxylum dipetalum*, ZanHaw = *Zanthoxylum hawaiiense*. *indicates fenced unit.

Exclosure	Acres	Asp Per	Chr Haw	Col Opp	Hap Hap	Hib Bra	Kok Dry	Mez Kav	Ner Ova	Not Bre	Por Scl	Sil Lan	Sol Inc	Ste Ang	Zan Dip	Zan Haw	Total
'Aiea	291									33							33
Anahulu I	255								4		1	30		15		9	59
Anahulu II	124								4							30	34
Uhiuhi 4	22							9									9
Hala pepe	92		62												1		63
Honohono	5				80												80
Henahena	731									20							20
Kauila Hala pepe	375		148	643						6							797
Kīpuka Oweowe*	26		1							6							5
Lama Koki'o	382		6	33			4			16							59
Pu'u Loa	530		30	5				2									37
Neraudia*	12								1								1
Po'ohoho'o *	29									6							6
FBS*	3744	45								3							47
Solanum Kīpuka	18												13				13
Stenogyne	10													43			43
Uhiuhi 1 *	13									1							1
Waihou II	202														2		2
Waihou I*	211									9					2		11
Zanthoxylum I*	7															7	7
Zanthoxylum II	815															129	129
Total Plants		45	247	681	80	65	4	11	9	100	1	30	13	58	5	175	1524

4.3.7 Preservation of natural plant communities and ecosystems

HRS §195-D-21(b)(1)(A) states: “*The plan will further the purposes of this chapter by protecting, maintaining, restoring, or enhancing identified ecosystems, natural communities, or habitat types upon which endangered, threatened, proposed, or candidate species depend within the area covered by the plan;*

Where:

‘Ecosystem’ means all natural elements, physical and biological, of the habitat or site in which any aquatic life, wildlife, or land plant species is found, and upon which it is dependent.

and

‘Natural communities’ means a natural assemblage of plants or animals that occurs within certain elevation, moisture, and habitat conditions.”

The HCP focuses on the preservation, management, and restoration of remnant native or degraded habitats and forest with the goal of creating or enhancing habitat for rare or listed plant and wildlife species including the Covered Species. The Covered Species and their associated habitat types are listed in Table 4.3. Some species overlap with other species because they have wide ranges and can be found in multiple habitat types.

Table 4.3 Listed species currently or historically found within the Plan Area categorized into plant clusters based on habitat type and range.

<p>Lowland Dry Forest</p> <p><i>Mezoneuron kavaiense, Colubrina oppositifolia, Hibiscus brackenridgei ssp. brackenridgei, Kokia drynarioides, Neraudia ovata, Nothoestrum breviflorum, Chrysodracon hawaiiensis, Silene lanceolata, Solanum incompletum, Polyscias sandwicensis</i></p>
<p>Mixed Mesic/Dry Forest</p> <p><i>Hibiscus brackenridgei ssp. brackenridgei, Kokia drynarioides, Nothoestrum breviflorum, Chrysodracon hawaiiensis, Silene lanceolata, Solanum incompletum, Zanthoxylum hawaiiense, Zanthoxylum dipetalum var. tomentosum, Euphorbia olowaluana, Melicope hawaiiensis, Polyscias sandwicensis</i></p>
<p>Mesic to Wet Forest</p> <p><i>Phyllostegia velutina, Vicia menziesii, Nothoestrum breviflorum, Exocarpus gaudichaudii, Fragaria chiloensis, Melicope hawaiiensis, Sisyrinchium acre, Tetramolopium consaguineum</i></p>
<p>Upland/ Dry Shrubland</p> <p><i>Haplostachys haplostachya, Neraudia ovata, Silene lanceolata, Solanum incompletum, Stenogyne angustifolia, Zanthoxylum hawaiiense, Euphorbia olowaluana, Eragrostis deflexa, Fragaria chiloensis, Sisyrinchium acre</i></p>

Table 4.4 Proposed and existing conservation units and exclosures categorized by habitat type.

<p>Lowland Dry Forest</p> <p>Kīpuka Oweowe, Hauaina, Uhiuhi 1, Ma‘o hau hele, Kauila Hala pepe, Boundary Kīpuka, Lama Koki‘o, Pu‘u Loa, Uhiuhi 4</p>
<p>Mixed Mesic/Dry Forest</p> <p>Waihou I, PWW Cone Conservation Area, Waihou II, Henahena, ‘Aiea, Po‘ohoho‘o</p>
<p>Mesic to Wet Forest</p> <p>Forest Bird Sanctuary, Po‘ohoho‘o</p>
<p>Upland Dry Shrubland</p> <p>Anuhulu I & II, Zanthoxylum I & II, Stenogyne, Honohono, Solanum Kīpuka, Kileo</p>

5.0 POTENTIAL IMPACTS

The issuance of an ITL requires establishing the number of individuals of (and habitat for) each Covered Species authorized for incidental take during a defined period. The following subsections describe potential direct and indirect impacts from the proposed Plan to the 15 federally and state listed plant species and the Blackburn's sphinx moth. Implementation of the measures described in Section 4.3 is expected to minimize the potential for take of species resulting from the proposed covered activities. Temporary impacts associated with maintaining fuelbreaks within the Plan Area are identified, as well as more permanent impacts resulting from game mammal management. The approach taken for estimating take levels for each species over a 25-year term is described in Section 5.3. Anticipated levels of take for the Covered Species are based on modeling and field surveys conducted within the Plan Area.

This section describes the activities within the Plan Area that will be covered by the incidental take license and for which the HCP provides avoidance, minimization, and mitigation for impacts to the Covered Species. Incidental take authorization is being sought for resource management, specifically game mammal management and associated hunting activities that are described in this section.

5.1 IMPACTS TO PLANTS

5.1.1 Grazing, Browsing, and Trampling

The only two mammals that are native to Hawai'i are the Hawaiian hoary bat (*Lasiurus cinereus semotus*) and the Hawaiian monk seal (*Monachus schauinslandi*). Because of this, native Hawaiian plants evolved in the absence of browsing and grazing mammals, and they often lack physical and chemical defenses that would help protect them.

Potential negative impacts from game mammal management activities on Covered Plant species are primarily in the form of direct take from grazing, browsing, and trampling. Appendix C describes a study done within the Plan Area that investigated the effects of ungulates on a number of the Covered Plant species. The results of the study indicate that those individuals outside of fences were negatively impacted by ungulates. Those *in situ* individuals of Covered Species that will be not protected by ungulate proof fences are considered subject to take and are covered under this HCP.

5.2 IMPACTS TO BLACKBURN'S SPHINX MOTH

Potential negative impacts to Blackburn's sphinx moth in the Plan Area are possible through the loss of native host plants ('Aiea) which are susceptible to ungulate browsing, grazing, and trampling, as well as loss of non-native host plants, such as tree tobacco, that now colonize roadsides and fuel-breaks across the Plan Area through road maintenance and clearing. Assessment of the cumulative impact of Plan actions on *M. blackburni* is discussed in this section.

5.2.1 Grazing, Browsing, and Trampling

Take of larvae on its native host plant, 'Aiea, due to direct and immediate ungulate pressure is unlikely, because the impacts of ungulate pressure may take years to cause tree death, and Blackburn's sphinx moth egg laying and larval development is seasonal. It has also been suggested that adult moths will take their time in finding suitable host sites for eggs (Kitching and Cadiou 2000), and therefore would be unlikely to lay eggs on a dead or dying 'Aiea. By the time an 'Aiea tree has senesced due to ungulate grazing or trampling adult moths will no longer lay eggs on the tree.

5.2.2 Clearing and Maintaining Fuelbreak Roads

Roadside and fuelbreak maintenance within the Plan Area is critical for at least two major reasons. First, clearing reduces the quantity of fine fuels that can lead to fires as well as prevents the spread of fire into new areas. And second, clearing these roads provides continued access for fire control vehicles, natural resource management, hunting, hiking, and educational and research visits. One of the primary shrubs being cleared on the roads and fuelbreaks is the non-native tree tobacco, which is a host plant for the Blackburn's sphinx moth. Clearing of roads and fuelbreaks (if not timed correctly) could potentially lead to the direct take of Blackburn's sphinx moth through loss of eggs and larvae. However, provisions put forth in this HCP (*see Section 4.3*) will avoid and minimize take to the greatest extent feasible. Fuelbreak roads need to be maintained free of vegetation year-round in order to adequately reduce fire risk. Fuelbreaks are created and maintained around each enclosure to limit the risk of fire within fenced units. Vegetation is cleared mechanically and with herbicides. Equipment used for clearing includes, but is not limited to:

- Skid sprayers with a boom and wand
- All-terrain vehicle and utility vehicle (ATV) battery pump sprayers
- Backpack sprayers
- Weed whackers
- ATV tow-behind brush/grass mowers
- Tractors
- Pruners, clippers, loppers, hand saws, chainsaws
- Small plastic containers for treating stumps
- Bulldozers

Fuelbreak roads are sprayed with herbicide after precipitation events that lead to vegetation regrowth. Most rainfall in the Plan Area occurs between December and May. The number of spraying events varies based on label instructions (i.e. allowable quantities) and vegetative growth, and can range from near zero (e.g., such as in drought years like 2010), to eight times a year. If vegetation has already consumed a large portion of the road or fuelbreak, then the vegetation is initially cleared with an ATV tow-behind brush/grass mower, a weed whacker, or a tractor. Once this vegetation has been cleared and a new flush of green growth has appeared, then herbicides are applied to prevent regrowth.

An herbicide product with the active ingredient glyphosate is typically used for road and fuelbreak maintenance. Application quantities are based on label instructions. A concentration of 1.5 - 3 percent is usually used depending on the time of year, amount, and type of vegetation. Lower concentrations can easily kill grasses, but higher concentrations may be needed to kill small trees or shrubs. A blue dye is used at approximately one ounce per gallon to mark areas where the herbicide has been sprayed. Broadcast spray is not effective on larger woody shrubs, and instead the cut and treat method is used. Loppers, clippers, handsaws, and chainsaws are typically used to cut the shrub, and then the stump is treated with a product with an active ingredient of Triclopyr. The Triclopyr product is often mixed with 70 percent crop oil (a surfactant that makes the herbicide stick to the stump) and blue dye. The types and quantities of pesticides used for road and fire fuelbreak maintenance may vary depending on factors such as cost, availability, evolved plant resistance to herbicide, and density. Regardless of the herbicides used, all label specifications and all regulations for use of herbicides in forested and natural areas will be followed for all vegetation control required in this HCP.

5.2.3 Clearing Tree Tobacco within Enclosures

Tree tobacco found within conservation units will be removed as part of invasive species management. Prior to removal, all tree tobacco will be surveyed for Blackburn's sphinx moth eggs and larvae. Unoccupied tree tobacco plants will be removed to prevent future use by the Blackburn's sphinx moth. Plants less than one meter tall will be removed by pulling, while plants greater than one meter tall will be cut and treated with herbicide. Should any larvae be found just prior to plant removal or cutting, the larvae will be removed and relocated by trained, authorized staff to a nearby location outside the area of disturbance that contains suitable moth habitat to avoid direct take.

5.3 ESTIMATING PLAN RELATED IMPACTS

This section focuses on methods used for estimating populations within the Plan Area. For plant populations, a model has been developed to estimate plant species abundance in the unsurveyed areas, and we use the HCP survey data and model to calculate take estimates for each plant species covered under this HCP. For *M. blackburni*, the distribution of tree tobacco was documented with the goal of calculating the acreage of Blackburn's sphinx moth habitat affected by road clearing and fuelbreak maintenance. These estimates were used to create a mitigation strategy for each of the Covered Species (*See Section 7, Implementation, for more information*).

5.3.1 Estimating Rare Plant Population Size

In order to estimate the size of Covered Plant Species populations within the Plan Area, we used a method based on 1) the number of plants found during HCP surveys, 2) the amount of area surveyed, and 3) the types of physical environments within which surveys took place. Because the Area of Potential Impact (Figure 1.2) includes all areas within 2.25 km of Pu'u Wa'awa'a and Pu'u Anahulu, we generated a 2.25 km buffer to reflect the entire action area (Figure 5.1). The Area of Potential Impact is defined as the Plan Area plus the buffer zone (*See section 1.3.1 for a full description of the Area of Potential Impact*). The buffer size was calculated using the home range data (see Appendix A) collected for pigs, sheep, and goats. Of the three game mammals that occur within the Plan Area, goats have the largest home range, 16.3 km. This 2.25 km buffer area is used to estimate the number of Covered Plant species potentially affected by game mammal management activities outside the boundary of Pu'u Wa'awa'a and Pu'u Anahulu. These abundance estimates are used to create the take estimates for each Covered Species and no actual management will occur within the 2.25 km buffer as the lands do not belong to the state.

Extensive surveys completed between 2003 and 2007 were focused in areas where rare species had been found in the past, as well as areas with the best remaining native dominated habitat. The 2003 -2007 survey data was used to estimate the areas with the highest likelihood of harboring Covered Plant species within the Plan Area. Estimates were then used to focus new plant surveys in 2011 on select areas (see Figure 3.3). Both data sets were combined to create a new estimate of the number of Covered Species that may occur in the unsurveyed areas of the Plan Area.

First, all of the point location data for each Covered Plant species was collated into a single GIS coverage. Next, we estimated the approximate area that was surveyed using the following assumptions. All surveys were recorded as track files on GPS device, and additional plant locations located away from these tracks represent areas where surveyors went; while it is logical to assume areas were surveyed along the way to these points, we have no way of knowing where these are, and therefore have slightly underestimated the area surveyed. Next, assuming each surveyor can perform a thorough visual sweep of the area up to 50 m from the path for herbaceous species, 100 m for ground survey of woody species, and 200 m for helicopter surveys of woody species, we generated buffers around all tracks and plant location points to estimate the entire area surveyed (Figure 5.2 and Figure 5.3).

The Plan Area is characterized by a large elevational gradient, a moderate range of moisture (relative to other areas in Hawai‘i - see Figure 5.4), an array of different substrate ages, and some variation in the land use and fire history. While some imagery and vegetation maps are available for the area, these are very general and provide little information with which to associate species with potential habitat. Additionally, fire maps are inadequate and provide little information about areas that have burned (and are therefore potentially less likely to harbor rare plants). Therefore, we used GIS layers of geologic substrate age (Wolfe and Morris 1996) and general climatic moisture (Price et al. 2012) to subdivide the region into distinct habitat units; because the “Moderately Dry” moisture zone extended from 500 m elevation up to 2,000 m elevation, we used a digital elevation model to divide all combinations involving that moisture zone at 1,100 m. The result is habitat units with different combinations of moisture, age, and elevation. In total, 35 habitat units were recognized (Figure 5.5).

By overlaying the surveyed areas against each habitat unit, we can determine how much of each habitat unit was surveyed. Overall, we estimate that 14% of the action area was surveyed with a capacity for detecting herbaceous species and 29% was surveyed with a capacity to detect woody species (both trees and shrubs). Ten habitat units had greater than 20% of their areas surveyed; however, four habitat units had less than 1% of their areas surveyed (in these cases no extrapolation can be made). Overall, most habitat units had sufficient areas surveyed to determine the likelihood that a given species might occur there. Furthermore, since the moisture and elevation limits have been mapped for each species (Price et al. 2012), further analysis was restricted to areas where each species could feasibly occur; this avoids over-estimation of potential habitat in the action area.

For each species, the number of individuals outside the survey areas and outside proposed or current exclosures was estimated. To do this, we first calculated the number of individuals of each Covered Species within the surveyed portion of each habitat unit. Then the average density of individuals recorded within each habitat type was estimated by dividing the number of individuals by the area of each habitat type surveyed. The average density was then used to estimate the number of individuals of each species within the areas of the same habitat units that were not surveyed. For example, imagine a habitat unit occupies 1 km² total, of which 20% was surveyed. If 10 individuals were recorded in the surveyed portion of the unit we would calculate a density of 10 individuals divided by 0.2 km² equaling 50 individuals/ km². By using this same value for the unsurveyed portion of the unit (0.8 km²), we would multiply the density of 50 individuals/ km² times 0.8 km², which equals 40 individuals. We obtained the total take estimate by summing the estimated number of individuals within the take area of each habitat, which in this example, totals 50 individuals.

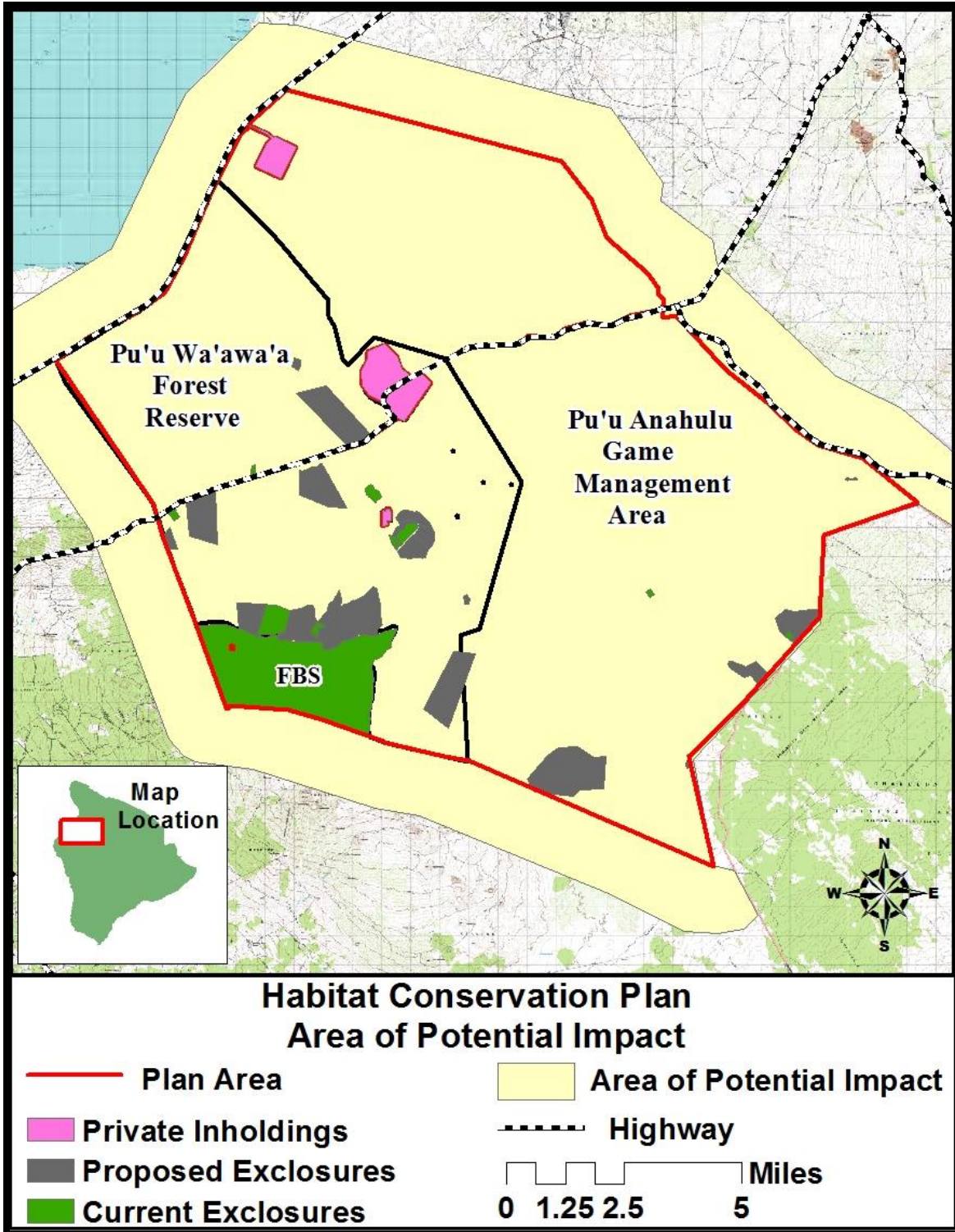


Figure 5.1 The HCP Area of Potential Impact including the 2.25 km buffer around all boundaries with the exception of PTA where a boundary fence prohibits the movement of ungulates.

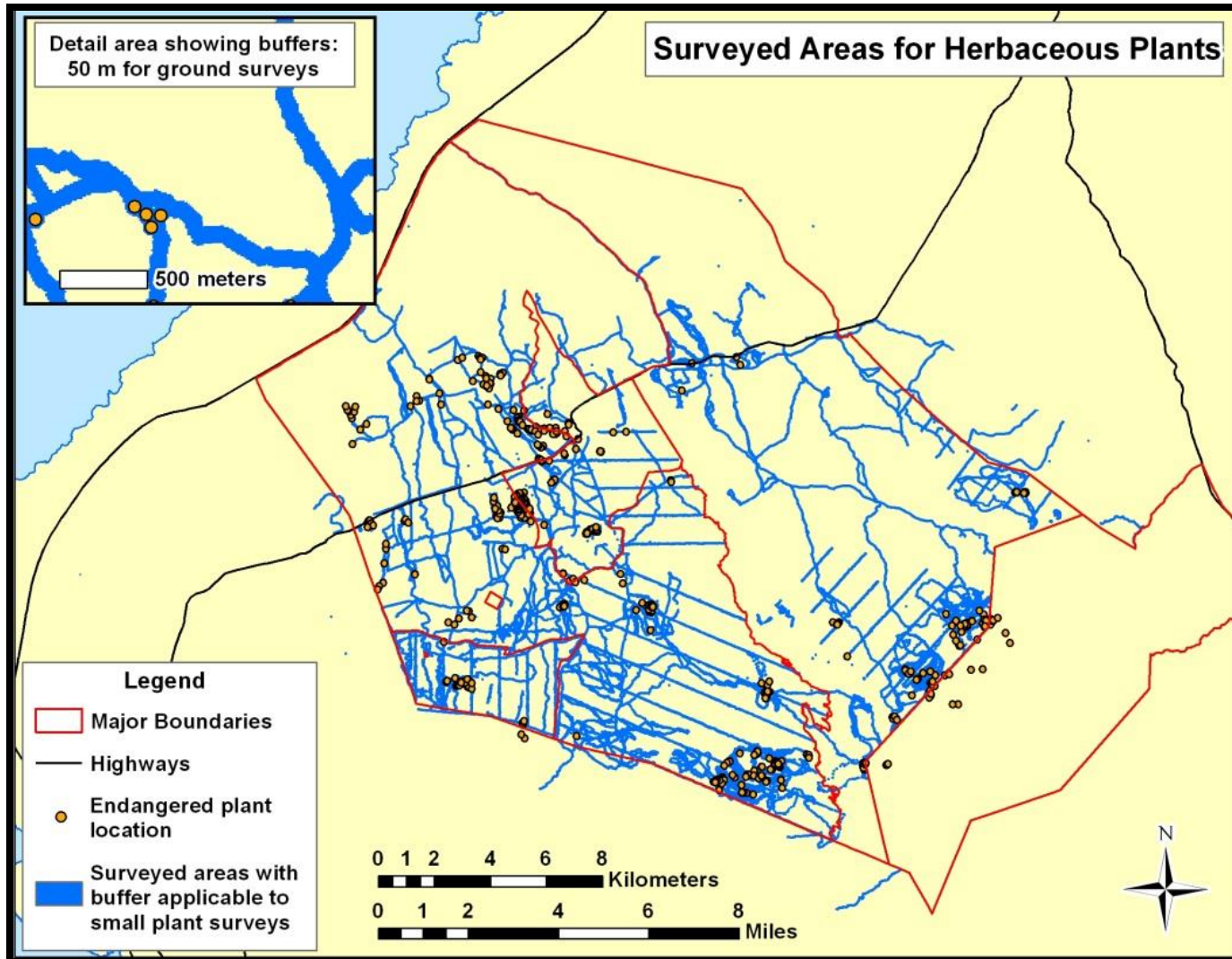


Figure 5.2 Surveyed areas within the Action Area including all 4x4 roads and a 50 m buffer around all tracks and guided searches for herbaceous species.

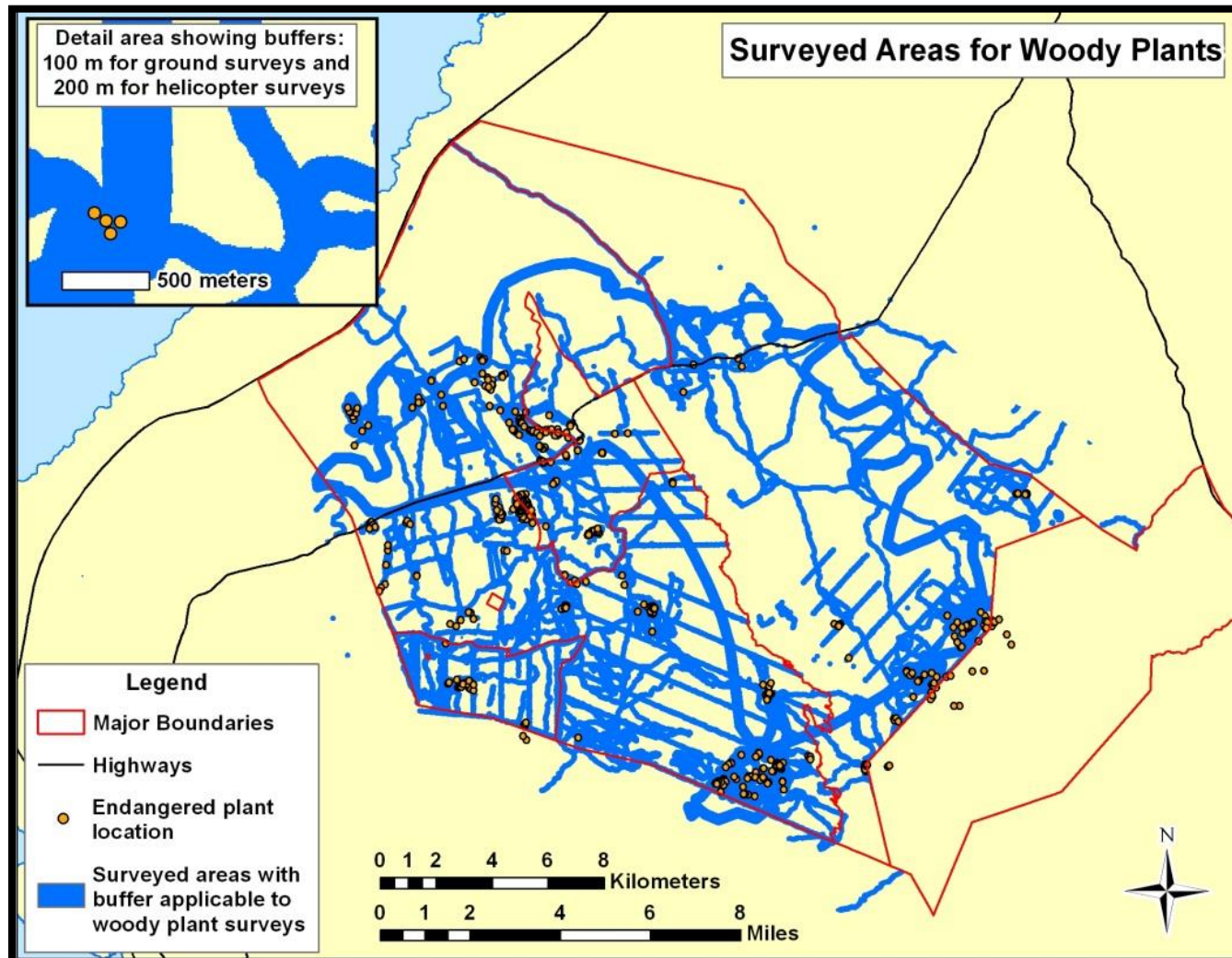


Figure 5.3 Surveyed areas within the Area of Potential Impact including all 4x4 roads and a 100 m buffer for ground and 200 m for helicopter surveys all tracks and guided searches for surveys of woody species.

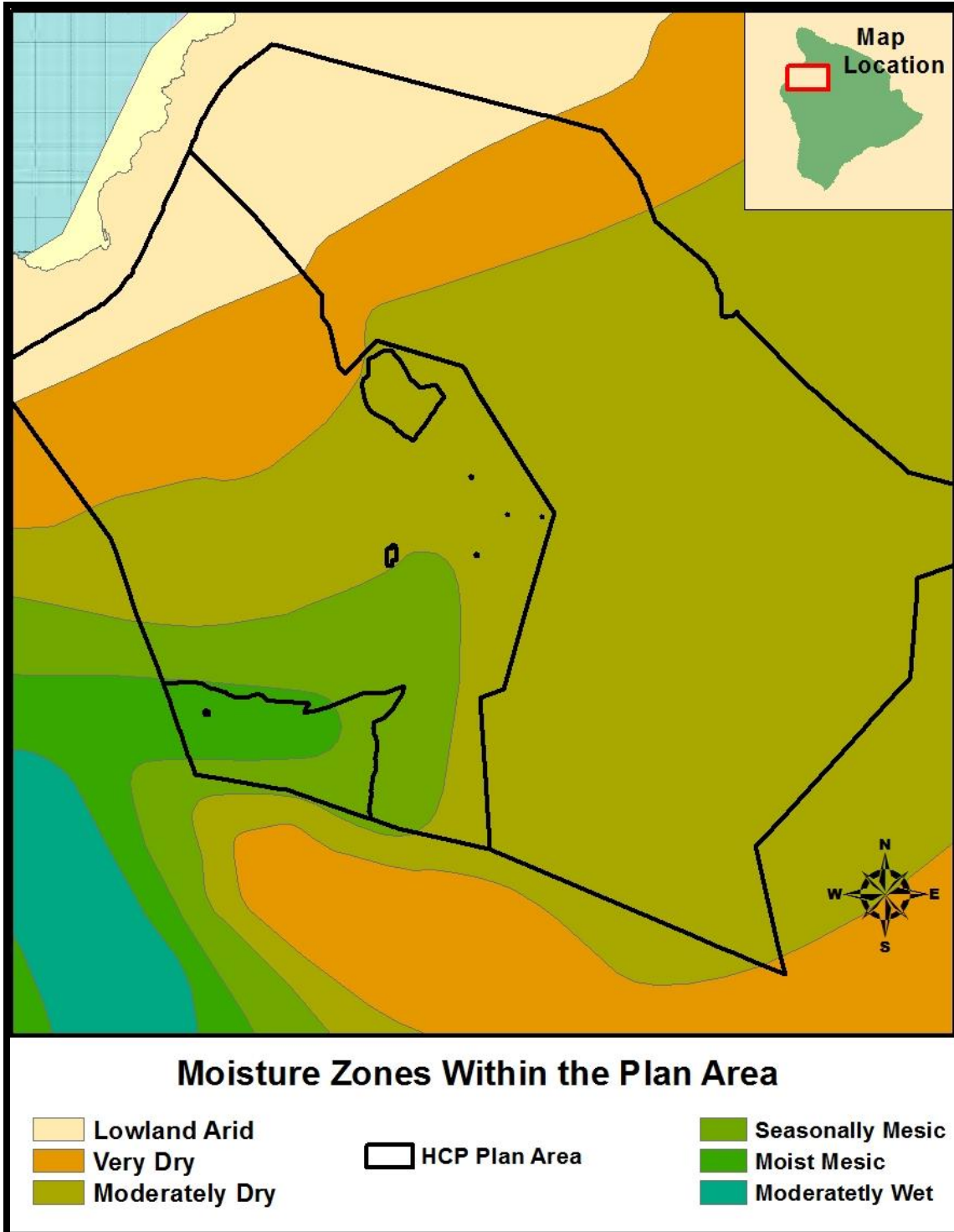


Figure 5.4 Moisture zones found within the Area of Potential Impact. Moisture zones were used as a proxy for elevation in defining habitat types for developing the model used to estimate number of plant individuals found outside of surveyed areas.

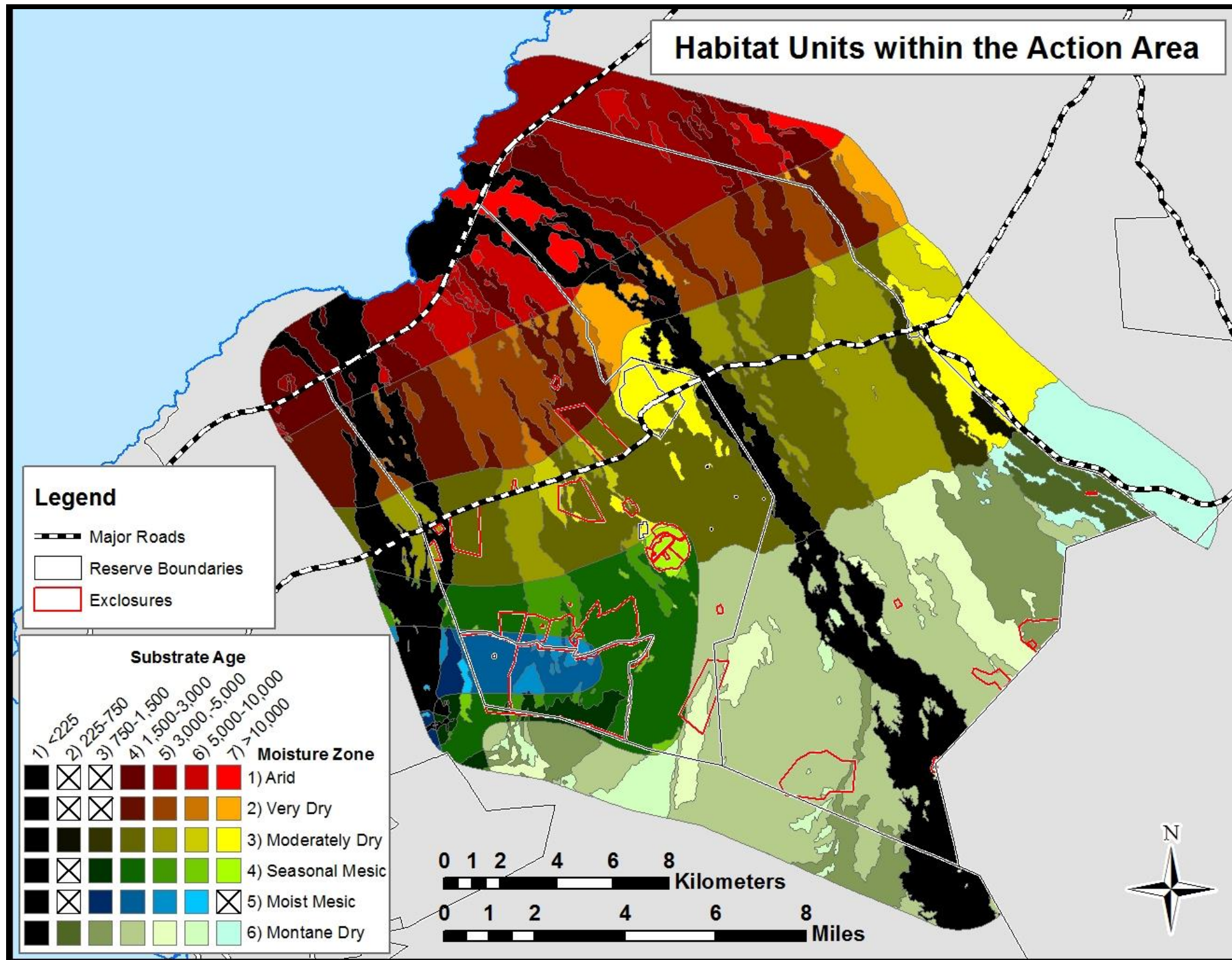


Figure 5.5 Habitat types found within the Area of Potential Impact as defined by moisture zone and substrate type.

5.3.2 Estimating Take of Covered Plant Species

Take estimates were calculated for each of the Covered Plant species using the HCP survey data (Table 5.1), the estimates generated from the model, and the location and size of the proposed and current exclosures. The number of known (surveyed) individuals is added to the estimated number of individuals (based on model predictions) to give a total population estimate. This information is summarized in Table 5.2 and details for each Covered Species and the corresponding exclosures are described below. The final numbers used in the plant model are based on the most up-to-date plant survey values. During the 2011 botanical surveys, the area proposed for the Kauila conservation unit was completely censused. Because the 2011 survey was more comprehensive and more accurate than those done during the 2003-2007 surveys, the 2011 results were used for this area and the previous data (2003-2007) were removed (*please see section 3.5.3 for details on botanical surveys*).

Table 5.1 Final plant numbers used for population modeling.

Scientific Name	Common Name	Number of Individuals
<i>Chrysodracon hawaiiensis</i>	Hala pepe	299
<i>Colubrina oppositifolia</i>	Kauila	739
<i>Haplostachys haplostachya</i>	Honohono	80
<i>Hibiscus brackenridgei</i>	Ma‘o hau hele	65
<i>Kokia drynarioides</i>	Koki‘o	4
<i>Mezoneuron kawaiense</i>	Uhiuhi	48
<i>Neraudia ovata</i>		9
<i>Nothoestrum breviflorum</i>	‘Aiea	156
<i>Silene lanceolata</i>	Hawaiian Catchfly	235
<i>Solanum incompletum</i>	Pōpolo kū mai	13
<i>Stenogyne angustifolia</i>		98
<i>Zanthoxylum dipetalum</i> var. <i>tomentosum</i>	A‘e	13
<i>Zanthoxylum hawaiiense</i>	A‘e	219

Table 5.2 Estimated take of Covered Plant Species. Estimates were only made within habitat types where the species was documented, and only within the known geographical range of the species (as given in (Price et al. 2012)). The area documented as surveyed differed according to whether the plant species is woody or herbaceous. We considered detection of an individual to be any 10 by 10 meter grid square that contains at least one surveyed plant location (see main text for explanation). Density was calculated as the number of detections divided by the area surveyed for each habitat. Unsurveyed take area consists of areas that have not been surveyed and lie outside of proposed or existing conservation exclosures. Estimated numbers of undetected plants represent the density of individuals detected in a given habitat multiplied by the unsurveyed take area.

Species	Habitat Type	% of habitat surveyed	Amount of habitat surveyed (km ²)	Number of individuals in habitat	Density of individuals (per km ²)	Unsurveyed take area (km ²)	Projected number of undetected plants in take area ¹⁸	Number of individuals in take area	Total projected take
<i>Chrysodracon hawaiiensis</i>	24	29.5	9.2	10	1.1	21.9	24	1	25
	34	49	30.5	212	7.0	24.8	173	42	214
	35	31.1	11.3	5	0.4	6.3	3	5	8
	36	21	1.7	7	4.1	15.7	65	1	66
	37	24.9	6.2	2	0.3	4	2	2	3
	44	50.9	4.7	1	0.2	4	1	1	2
	47	47.6	0.5	62	124	0.1	13	0	12
	Total	36.9	58.1	299	4.7	76.8	279	52	331
<i>Colubrina oppositifolia</i>	24	32.1	8.7	3	0.3	18.2	7	1	7
	34	49.8	29.5	723	24.5	28.6	701	51	752
	35	30.5	10.6	4	0.4	23.9	10	4	13
	36	21.0	1.7	8	4.7	6.3	30	1	31
	44	45.7	2.8	1	0.4	3.1	2	1	2
	Total	39.4	53.3	758	14.2	80	767	58	805

¹⁸ In cases where a take of a partial individual is calculated, the values are rounded up.

Species	Habitat Type	% of habitat surveyed	Amount of habitat surveyed (km ²)	Number of individuals in habitat	Density of individuals (per km ²)	Unsurveyed take area (km ²)	Projected number of undetected plants in take area ¹⁸	Number of individuals in take area	Total projected take
<i>Haplostachys haplostachya</i>									
	67	9.0	1.8	80	44.4	17.9	796	0	796
	Total	9.0	1.8	80	44.4	17.9	796	0	796
<i>Hibiscus brackenridgei</i>									
	34	51.5	25.3	65	2.6	22.7	59	0	58
	Total	51.5	25.3	65	2.6	22.7	59	0	59
<i>Kokia drynariodes</i>									
	34	92.6	20.3	4	0.2	1.3	1	0	1
	Total	92.6	20.3	4	0.2	1.3	1	0	1
<i>Mezoneuron kavaiense</i>									
	24	29.0	9.0	28	3.1	21.9	69	17	85
	25	34.1	9.3	20	2.2	18.0	39	20	59
	Total	31.4	18.3	48	2.6	39.9	107	37	144
<i>Neraudia ovata</i>									
	63	23.3	4.1	4	1.0	13.2	13	1	14
	64	25.7	13.7	4	0.3	39.1	12	0	11
	65	18.7	3.2	1	0.3	13.9	5	0	4
	Total	23.9	21.0	8	0.4	66.2	28	1	29
<i>Nothoestrum breviflorum</i>									
	24	29.5	9.2	1	0.1	25.1	3	1	4
	31	12.6	2	3	1.5	13.8	21	2	23
	34	49	30.5	43	1.4	30.6	44	22	65
	35	31.1	11.3	8	0.7	24.8	18	1	19
	41	1.9	0.1	2	20.0	3.8	76	2	78
	44	60.4	16.8	78	4.6	8.2	39	25	63
	45	37.2	2	6	3.0	2.5	8	0	8
	46	51.2	0.6	2	3.3	0.5	2	2	4

Species	Habitat Type	% of habitat surveyed	Amount of habitat surveyed (km ²)	Number of individuals in habitat	Density of individuals (per km ²)	Unsurveyed take area (km ²)	Projected number of undetected plants in take area ¹⁸	Number of individuals in take area	Total projected take
		47	41.5	0.8	1	1.3	0.1	1	1
		54	70.4	5.4	10	1.9	0.3	1	0
		55	59.5	1.4	2	1.4	0.4	1	0
	Total	40.3	80.1	156	2.5	110.1	211	79	265
<i>Silene lanceolata</i>									
		61	6.6	1.8	79	43.9	25.8	1132	79
		63	19.8	4.7	35	7.4	18.7	139	5
		64	26.2	19.1	121	6.3	53.1	336	121
	Total	18.6	25.6	235	9.2	97.6	1607	205	1812
<i>Solanum incompletum</i>									
		61	6.6	1.8	4	2.2	25.8	58	0
		65	21.1	4.1	8	2.0	15.3	30	0
	Total	27.7	5.9	12	2.0	45.3	87	0	87
<i>Stenogyne angustifolia</i>									
		63	19.8	4.7	15	3.2	18.7	60	0
		64	26.7	19.2	83	4.3	52.1	226	40
	Total	46.5	23.9	98	4.1	70.8	285	40	325
<i>Zanthoxylum dipetalum</i>									
		44	57.7	10.5	8	0.8	6.1	5	5
		45	35.9	1.7	4	2.4	2.5	6	3
		47	40.4	0.8	1	1.3	0.1	1	0
	Total	52.1	13.0	13	1.0	8.7	11	8	19
<i>Zanthoxylum hawaiiense</i>									
		61	18.8	4.1	3	0.7	17.6	13	3
		63	47.0	10.1	13	1.3	11.3	15	1
		64	49.5	33.9	203	6.0	24.4	147	40
	Total	43.1	48.0	219	4.6	63.3	176	44	218

5.3.3 Loss of Recruitment

Those individuals of Covered Species that occur outside of current and proposed fenced units are considered unprotected and will be included within the take estimate. Propagules from these individuals will be collected to ensure genetic representation in mitigation populations. In addition to the loss of these individuals, concern has been raised about the loss of recruitment from these unprotected individuals. In order to address this concern, one additional population (following stabilization criteria) will be created for each of the Covered Species to mitigate for this potential loss of recruitment. Monitoring will be done to estimate the level of potential take of seeds that germinate around unprotected plants and are harmed as a result of Covered Activities. For each of the Covered Plant Species, a minimum of 10 fenced individuals (where 10 individuals still exist) will be monitored on an annual basis (for five years) to count the number of recruited individuals and estimate an average recruitment for that species. An estimated rate of loss of recruitment will be calculated for each species. Should values calculated from monitoring data exceed those proposed for in the stabilization criteria, the additional values will be added to the overall take estimate (*For more detailed description of methods please see the Monitoring Section 7.2*).

5.3.4 Strategies for Stabilization of Covered Species

The focus for the stabilization of threatened and endangered species occurring within the Plan Area will be on restoration and protection of functional native plant communities. These communities should support not only stable Covered Species populations, but represent fully functional (in so far as possible), self-sustaining communities with eventual minimal dependence on human management. Measures of success for the purposes of the HCP are necessarily focused on specific protected species, but our management approach (per HRS §195 D-1, -4, and -21) recognizes that these species may never be truly stable and protected unless they are part of a functioning community.

The first step in developing our management strategy is to identify and use areas within the Plan Area that contain established native overstory tree species within which a matrix of rare and endangered species can be managed. Those populations of listed species located in areas with higher quality habitat will have priority and will be managed for stability. Those populations or individuals located in degraded habitat will be individually fenced and used primarily as propagule sources to maintain genetic diversity of outplanted areas. Within the first five years of HCP implementation, all propagule source plants will be mapped and database created to track what individuals have been collected from and which individuals still need genetic representation.

The U.S. Fish and Wildlife Service (USFWS) defines plant stabilization according to the recommendations put forth by the Hawai'i and Pacific Plants Recovery Coordinating Committee (HPPRCC), a group of botanical experts gathered together by the USFWS to offer guidance on the recovery of listed plants in the Pacific (Army 2003b). The HPPRCC states that a species is considered to be stable if it meets the following three criteria: 1) it has sufficient numbers of regenerating individuals in a minimum number of populations (specified below); 2) its threats are controlled at these populations; and 3) these populations are fully represented in an *ex situ* collection (USFWS 1999). A

population in this context is defined and used here as 1) a given number of individuals found less than 1,000 m apart, that 2) are presumably genetically similar and therefore capable of outcrossing, and 3) are equally affected by localized stochastic events such as fire (Army 2003b). It is important to note that the requirements for stabilization are far below those required for delisting or down listing, and that stabilization is not synonymous with recovery.

The HPPRCC (1994) recommends the following population stability goals: three populations of plants with a minimum of either 25 mature and reproducing individuals of long-lived perennials (>10 year life span), 50 mature and reproducing individuals of short-lived perennials (<10 year life span), or 100 mature and reproducing individuals of annual taxa per season (<1 year life span). The HPPRCC (1994) outlines that sustaining populations with these numbers of reproducing individuals over the short-term will ensure that there will be an adequate reservoir of younger individuals that can develop into mature, reproducing plants with each subsequent generation to prevent extinction. However, this approach is not adequate long-term to achieve full recovery of the taxon (Army 2003b).

Factors that will be considered when assessing mitigation goals for this HCP include threats that contribute to the decline of the target taxa and aspects of their biology (especially reproductive biology) that are pertinent to natural regeneration, as well as the state of knowledge regarding propagation, cultivation, and *in situ* care of wild individuals.

Reintroduction and augmentation of Covered Species will follow the guidelines set forth by the Hawai'i Rare Plant Restoration Group (HRPRG) (Army 2003a). By definition, reintroduction is the introduction of individual(s) of a given species into an area of known historical range where no individuals currently occur (Army 2003b, a). Augmentation is defined as the introduction of propagules or individual(s) of a given species into an area in which a population is currently extant (Army 2003b, a). In both cases a number of considerations must be taken, particularly relating to genetic integrity. Specific guidelines will be developed to ensure mitigation efforts will not harm or endanger current extant populations of listed species.

5.3.5 Factors Influencing Effective Population Size

Effective population (N_e) size is the average number of individuals in a total population (N) that actually contribute genes to succeeding generations. The following factors may influence the effective population size of plant species thereby requiring a larger number of individuals needed to reach an equivalent N_e . For this reason, these factors will be considered during mitigation planning on a species by species basis (Table 5.2).

1. Obligate outcrossing: The fertilization of a flower of a genetically distinct individual by the pollen of another genetically distinct individual is known as outcrossing. For taxa incapable of self-fertilization, outcrossing is obligatory, meaning if there is no outcrossing there will be no viable offspring produced. Once a population of an obligately outcrossing taxon becomes too small, or the distance between individual plants increases beyond the range of pollination mechanisms, the population's regeneration rate may decrease, leading to a decline

in the number of individuals recruited annually. **Therefore, for taxa that obligately outcross, the base population target should be doubled.**

2. Dioecy: Dioecy is the condition in which an individual plant produces only functionally staminate (male) or pistillate (female) flowers. Dioecious plants require the presence of both male and female individuals within pollination range that are flowering at the same time in order to effect fertilization and successful seed set. It is therefore much more difficult to ensure conditions for regeneration with dioecious taxa.
3. Vegetative reproduction: Plants that reproduce vegetatively produce clones of themselves, so that an area that appears to be composed of unique individuals may actually be composed of many genetically identical individuals. These groups of individuals are often more genetically similar within populations and more distinct between populations than taxa that reproduce sexually.
4. Infrequent or inconsistent flowering: Since flowering is a key component of reproduction, any inconsistency in flowering or reduction in the frequency of flowering reduces N_e and therefore reduces the likelihood of maintaining population stability. For example, there are some cases where, although the great majority of individuals in a population flower, flowering occurs infrequently. The likelihood of environmental events (e.g., droughts, fires, storms) reducing mass flowering and successful fruiting is much greater for plants that flower sporadically or infrequently than for plants that flower more regularly or frequently. **In those taxa with known infrequent or inconsistent flowering, the population target is doubled.**
5. Large percentage of non-flowering or non-fruiting plants: This problem is similar to the infrequent or inconsistent flowering factor described above, but concerns populations in which, even during peak flowering times, the majority of individuals do not flower, or are not able to produce fruit or seed. **N_e is much lower than N in this case, and the population target is doubled.**
6. Low seed set or poor seed viability: Low seed set or poor seed viability, whether due to seed predation, disease, pollination failure, or other factors, can potentially lead to decreases in reproductive potential. **For taxa with low seed set or poor viability, the target population goal is doubled.**
7. Tendency for large declines or fluctuations in population size: Large declines in population size, even if balanced by large increases at other times, reduce the stability of the population through a reduction in N_e . Any negative events during a major low point in a population fluctuation could extirpate the population. **For taxa prone to large declines or fluctuations in population sizes, the population target is doubled.**
8. Persistence of the seed bank: This factor does not warrant increasing the population target, but suggests that surveys of historical occurrences should be conducted to check for regeneration from the seed bank, even years after the last observation of mature individuals at the site. A persistent seed bank in a population of short-lived individuals could buffer fluctuations in population size.

For many of the listed species in the Plan Area basic life history information such as phenology, pollinators, and seed viability is lacking. For this reason, mitigation goals may be adjusted as new information becomes available. Utilizing the HCP plant survey data, those areas containing the highest quality habitat and greatest number of Covered Species will be selected and prioritized for conservation. For each species, we used the population estimates (Table 5.1) in conjunction with the identification of those factors that may influence effective populations size (Table 5.2) to determine mitigation goals for each covered plant species (*See section 6.3 for species specific mitigation goals*). Species stabilization guidelines will also be used to set goals for additional populations that must be established to provide a net benefit for each Covered Species. In addition, we identified sites for potential reintroduction (*see section 6.1*), as well as future augmentation needs for each species. Future plans include documenting the health and threats to plants within both proposed and current exclosures (i.e. weeds, compromised fences etc).

Table 5.3 The life form (SP= short-lived perennial, LP= long-lived perennial) and factors affecting effective population size for Covered Species in the Plan Area.

Scientific Name	Common Name	Life Form	Applicable Factors
<i>Asplenium peruvianum</i>		SP	Unknown
<i>Mezoneuron kavaianse</i>	Uhiuhi	LP	Tendency for large declines or fluctuations in population size (wildfire)
<i>Colubrina oppositifolia</i>	Kauila	LP	Unknown
<i>Haplostachys haplostachya</i>	Honohono	SP	Tendency for large declines or fluctuations in population size (wildfire, drought)
<i>Hibiscus brackenrdgei</i>	Ma‘o hau hele	SP	Unknown
<i>Kokia drynarioides</i>	Koki‘o	SP	Infrequent and inconsistent flowering
<i>Neraudia ovata</i>		SP	Dioecious
<i>Nothoestrum breviflorum</i>	‘Aiea	LP	Unknown
<i>Chrysodracon hawaiiensis</i>	Hala pepe	LP	Unknown
<i>Portulaca sclerocarpa</i>	Po‘e	SP	Unknown
<i>Silene lanceolata</i>	Hawaiian Catchfly	SP	Unknown
<i>Solanum incompletum</i>	Pōpolo kū mai	SP	Vegetative reproduction, infrequent/inconsistent flowering, large percentage of non-flowering/fruited plants, low seed set/poor seed viability
<i>Stenogyne angustifolia</i>		SP	Unknown
<i>Zanthoxylum dipetalum</i>	A‘e	LP	Dioecious, large percentage of non-flowering/fruited plants, low seed set/poor seed viability
<i>Zanthoxylum hawaiiensis</i>	A‘e	LP	Dioecious

Table 5.4 Species stabilization goals for each of the Covered Species.

Scientific Name	Common Name	Populations	Individuals	Threats to Mitigate
<i>Asplenium peruvianum</i>		3	50	fire, invasive species, ungulates
<i>Mezoneuron kawaiense</i>	Uhiuhi	3	50	fire, invasive species, ungulates
<i>Colubrina oppositifolia</i>	Kauila	3	25	fire, invasive species, ungulates
<i>Haplostachys haplostachya</i>	Honohono	3	100	fire, invasive species, ungulates
<i>Hibiscus brackenridgei</i>	Ma‘o hau hele	3	50	fire, invasive species, ungulates
<i>Kokia drynarioides</i>	Koki‘o	3	100	fire, invasive species, ungulates
<i>Neraudia ovata</i>		3	100	fire, invasive species, ungulates
<i>Nothoctrum breviflorum</i>	‘Aiea	3	25	fire, invasive species, ungulates
<i>Chrysodracon hawaiiensis</i>	Hala pepe	3	25	fire, invasive species, ungulates
<i>Portulaca sclerocarpa</i>	Po‘e	3	50	fire, invasive species, ungulates
<i>Silene lanceolata</i>	Hawaiian Catchfly	3	50	fire, invasive species, ungulates
<i>Solanum incompletum</i>	Pōpolo kū mai	3	100	fire, invasive species, ungulates
<i>Stenogyne angustifolia</i>		3	50	fire, invasive species, ungulates
<i>Zanthoxylum dipetalum</i>	A‘e	3	50	fire, invasive species, ungulates
<i>Zanthoxylum hawaiiensis</i>	A‘e	3	50	fire, invasive species, ungulates

5.3.6 Estimating Blackburn's Sphinx Moth Habitat Affected by Road and Fuelbreak Maintenance

In 2011 and 2012 the distribution of tree tobacco on roadsides and fuelbreaks was mapped across the Plan Area. Tree tobacco locations were recorded as HCP staff drove a subset of 4x4 roads expected to contain tree tobacco from previous observations. For each location logged, the number of trees within a 25 m x 3 m belt transect was recorded. Tree tobacco locations were recorded on both sides of the road. These locations were used to create a preliminary map of the distribution of tree tobacco across the surveyed area (Figure 5.6). We then used a subset of this data taken in Pu'u Anahulu, to calculate what proportion of the roads that are expected to contain tree tobacco actually are occupied by tree tobacco. For a stretch of road 37,402 m long and 7 m wide (261,814 m²), 649 tree tobacco location survey points were recorded. Each survey point represents a 25 m x 3 m long belt transect that contains tree tobacco. For the subset of road used in this calculation, the total area actually occupied by tree tobacco was 48,675 m² or approximately 18.6% of the surveyed roads.

Next, a map of the Core Tree Tobacco Invasion Area (CTTIA) was created to indicate which roads in the Plan Area currently contain, have contained in the past, or may contain tree tobacco in the future (Figure 5.7). Based on this map, we estimate the CTTIA to be 839,486.38 m² or approximately 207 acres. If we assume that the coverage measured above in general characterizes the density of tree tobacco as a whole across the Plan Area (and this is likely a conservative estimate as Pu'u Anahulu tends to have high density), then we can apply this value to the CTTIA (839,486.38 m² x 0.186), to calculate the area occupied by tree tobacco (Occupied Area = 156,144.467 m² or 38.6 acres).

5.3.7 Tree Tobacco and Blackburn's Sphinx Moth Population Estimate in the Plan Area

We estimated the location and distribution of tree tobacco in the Plan Area based on a helicopter survey conducted in January 2015 (see Figure 5.7). During the helicopter survey, track files and waypoints were taken to map the outer edges of infestation areas as well as map individual tree tobacco locations in less colonized areas. Based on this survey, we estimate that approximately 6,462 acres of the Plan Area (outside of roads) contain tree tobacco (6% of the Plan Area). The winter 2012 off-road BSM survey data was then used to estimate BSM density. A total of 17 Blackburn's sphinx moth detections (larvae and un-hatched eggs) were found on 557 tree tobacco plants across 38 transects. One transect has an area of 75 m² (25 m x 3 m). Using these data, we calculated: the area surveyed as 2,850 m² (38 x 75 m²) and BSM density as 0.006 BSM/m² (17/2850 m²) or 24.1 BSM per acre. Based on the tree tobacco distribution estimated above, the population estimate for Blackburn's sphinx moth larvae and un-hatched eggs outside of roads is 155,734 BSM (24.1 x 6462 = 155,734.2).

An on-road estimate was calculated based on a total of 56 Blackburn's sphinx moth detections (larvae and un-hatched eggs) found on 1766 tree tobacco plants across 80 transects. One transect has an area of 75 m² (25 m x 3 m). Using these data, we calculated: the area surveyed as 6,000 m² (80 x 75 m²) and BSM density as 0.009 BSM/m² (56/6,000 m²) or 37.8 BSM per acre. Based on the Occupied Area calculated

above (38.6 acres), estimated take for one winter clearing period rounds up to 1458 Blackburn's Sphinx moth individuals ($37.77 \times 38.6 = 1457.9$ larvae plus un-hatched eggs). We then added the winter 2012 on-road population estimate (1,458 BSM) to the Off-road estimate for a total winter Blackburn's sphinx moth population estimate of 157,445 individuals (larvae plus un-hatched eggs).

5.3.8 Estimating Blackburn's Sphinx Moth Take (Based on (USFWS 2015e))

We are requesting take of Blackburn's sphinx moth based on following a schedule that allows DOFAW to clear the roads and fuel-breaks year-round, which is critical to reducing the risk of a catastrophic wildfire. Studies conducted in the Plan Area indicate that larvae and egg densities are highest in the winter months which tend to be the wettest months in the Plan Area. However, weather patterns may be unpredictable and increased rains may extend the larval season (similarly drought conditions may restrict the larval season). Whenever possible control and removal will be timed to reduce adverse effects to Blackburn's sphinx moth eggs and larvae; tree tobacco, especially over one meter tall, will be controlled during dry periods (summer months). In general, tree tobacco clearing will occur year-round at intervals designed to prevent new growth from exceeding one meter. This clearing schedule will reduce the number of eggs and larvae on roads and fuel breaks and minimize the amount of take anticipated to occur as a result of the Covered Activity.

The loss of tree tobacco within roads and fuelbreaks will not substantially reduce the amount of Blackburn's sphinx moth habitat in the North Kona region. There are an estimated 6,500 acres of tree tobacco in the Plan Area both on and off roads/fuel breaks. However, the density of tree tobacco differs between on and off roads/fuel breaks (Table 5.5), with more tree tobacco plants per meter on roads/fuel breaks. As calculated in Table 5.5, the loss of 38.6 acres of tree tobacco within the roads and fuel breaks constitutes 0.9 percent of the total number of tree tobacco plants that serve as Blackburn's sphinx moth habitat in the Plan Area. This does not include 'Aiea within the Plan Area, nor thousands of acres of tree tobacco outside the Plan Area. Given the rate at which tree tobacco is spreading in the Plan Area, it is likely that these 38.6 acres lost will quickly be replaced by new growth of tree tobacco elsewhere.

Clearing tree tobacco from roads and fuel breaks will likely result in direct mortality of BSM eggs and larvae as tree tobacco is cut down. Incidental take of Blackburn's sphinx moth will be difficult to detect and impossible to accurately quantify for the following reasons.

First, take of Blackburn's sphinx moth is difficult to detect because of the small size and cryptic nature of its eggs and newborn larvae, as well as the density at which the larvae and eggs occur on the landscape. Blackburn's sphinx moth eggs and larvae are hard to find. Eggs are approximately 1.5 mm in diameter, newly hatched larvae are approximately one cm long and ~one mm wide, both are similar colors to the leaves of tree tobacco, and often loiter in cryptic areas on the undersides and folds of leaves. Furthermore, eggs and larvae can be present in very low densities. For instance, during the winter of 2012, which was during the wet part of the year when *more* BSM were present, there were still only 0.03 larvae/eggs per plant, or roughly 1 larvae/egg per 33 stems. Because some surveyed plants had multiple eggs and/or larvae, less than 3 percent

of tree tobacco surveyed had eggs or larvae on them. Secondly, quantifying the anticipated amount of take is nearly impossible given the seasonal and annual variability of the species. The density of Blackburn's sphinx moth in the Plan Area fluctuates annually and seasonally by at least an order of magnitude, e.g. 20 egg/19.5 larvae per hectare in the winter of 2011 to 1.6 eggs/0.4 larvae per hectare in the summer of 2012. In addition, 2011 and 2012 were years of low rainfall in the Plan Area compared to 2014 and thus do not necessarily represent BSM densities and distribution in wetter years. However, 2011 and 2012 are considered wet years relative to 2009 and 2010.

The level of take of Blackburn's sphinx moth can be anticipated by the proportional loss of tree tobacco in the Plan Area. Surveys show that there is no significant difference between the density of Blackburn's sphinx moth eggs and larvae on tree tobacco *on* roads/fuel breaks (0.0312 larvae/eggs per tree tobacco) versus *off* roads/fuel breaks (0.0305 larvae/eggs per tree tobacco). Therefore, whatever proportion of tree tobacco is cut down in the Plan Area, the same proportion of Blackburn's sphinx moth eggs and larvae will experience take. One important note however, is that there is a difference in the density of tree tobacco plants on and off roads/fuel breaks, with higher densities being on roads/fuel breaks (Table 5.5). Taking those two factors into account, clearing roads/fuel breaks will account for 0.9 percent of the tree tobacco in the Plan Area. Therefore, given that 0.9 percent of the available tree tobacco will be cleared in the Plan Area, we estimate that 0.9 percent of Blackburn's sphinx moth larvae and eggs will be taken in the process. In reality the percentage of larvae and eggs taken in the Plan Area is almost certain to be less on an annual basis. Use of tree tobacco by Blackburn's sphinx moth correlates strongly with plant height; surveys found that only 1.9 percent of tree tobacco < one meter tall have Blackburn's sphinx moth eggs and/or larvae whereas 23.1 percent of plants 1-2 m and 67.3 percent of plants 2-5 m tall have eggs and/or larvae (See Appendix D). Given that DOFAW will clear roads and fuel breaks regularly year-round, the majority of tree tobacco regrowth will be less than one meter when cleared, which will minimize the number of eggs and larvae on roads and fuel breaks during subsequent maintenance, thereby reducing direct mortality of Blackburn's sphinx moth.

Improved access through routinely clearing four wheel drive roads, as well as vegetation free fuelbreaks, will have a beneficial effect to the moth by reducing the chances that a fire destroys its native or non-native habitats. Given the spread of readily ignitable fuels such as fountain grass (*P. setaceum*) throughout the Plan Area, projections of decreasing rain due to El Nino and climate change, and past fire history in and around the Plan Area, fire control is critical.

Table 5.5 Densities of tree tobacco on and off roads/fuel breaks, and proposed proportional clearing of tree tobacco.

Road/Fuel break	Tree tobacco Area (hectare)	Tree tobacco per hectare	Est. number of Tree tobacco	Percent of Tree Tobacco
On	15.6	2,940	45,925.4	0.9%
Off	2,615.0	1,950	5,099,407.8	99.1%
Total	2,630.7	NA	5,145,333.2	100.0%

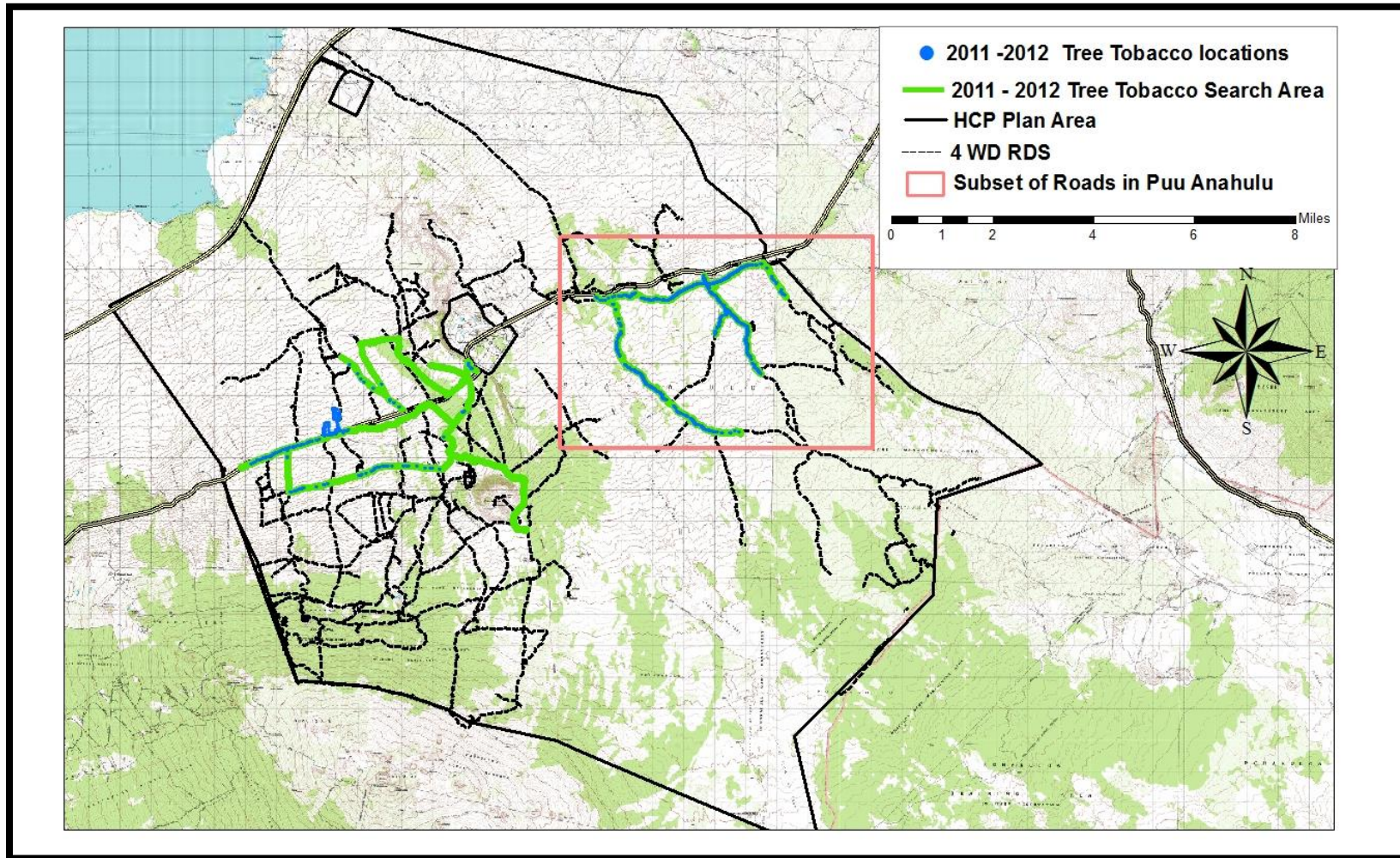


Figure 5.6 2011 and 2012 tree tobacco search area (green line) with mapped tree tobacco locations (blue dots). The area in the red/pink rectangle highlights the subset of roads used to calculate the proportion of occupied habitat.

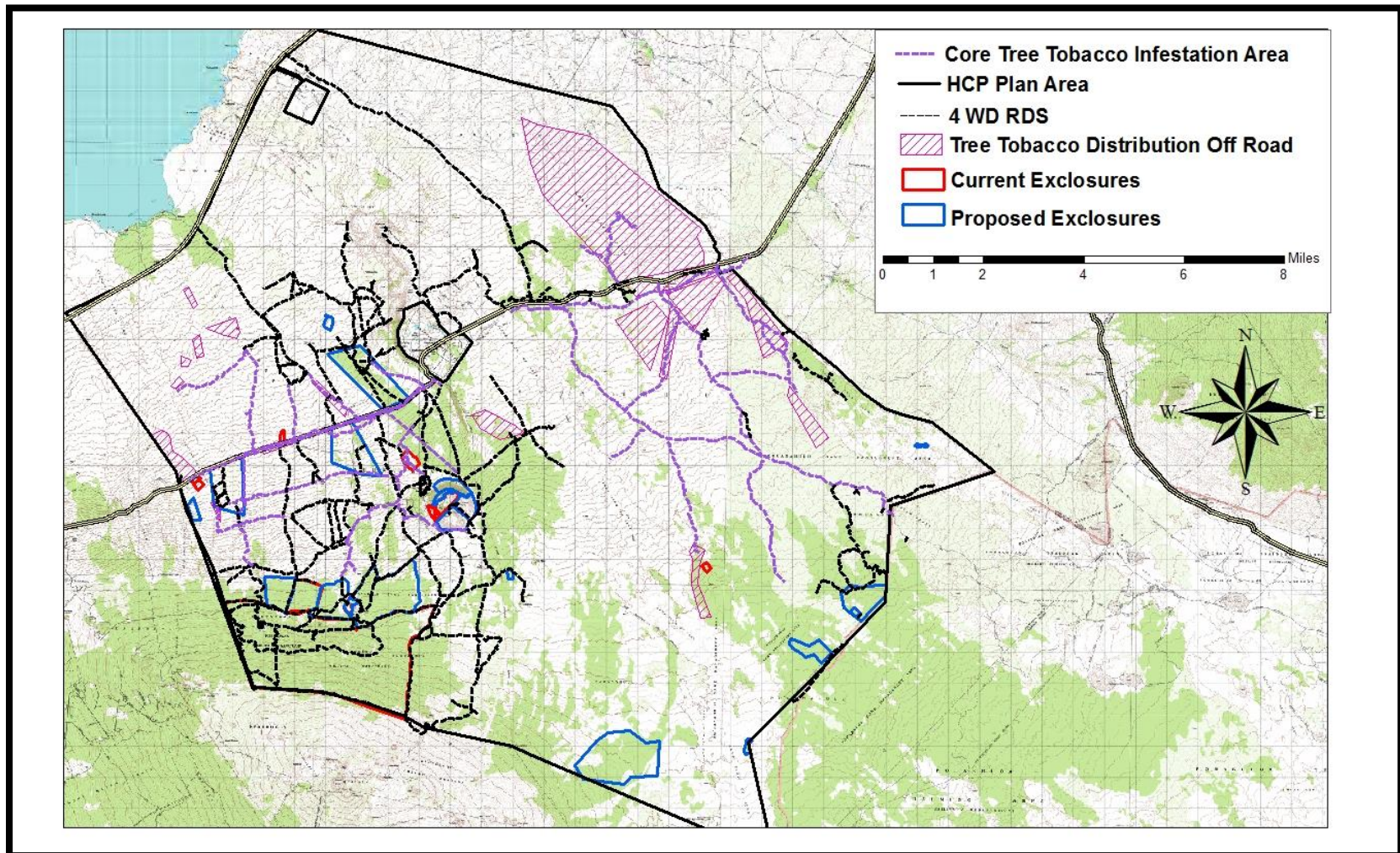


Figure 5.7 Estimated tree tobacco distribution in the Plan Area based on the 2015 helicopter survey (pink hashed area). Roads in purple indicate the CTTIA.

6.0 MITIGATION

In addition to the need for avoidance and minimization measures, HRS Chapter §195-D-4 requires that an HCP describe the steps that will be taken to mitigate the effects of the taking authorized by the proposed ITL. Unlike incidental take avoidance and minimization measures (Section 4.3), which are designed to reduce the amount of take, mitigation measures are designed to offset or compensate for the actual effects of unavoidable incidental take that occurs under the HCP.

DLNR has worked with the ESRC to identify and select appropriate mitigation measures to compensate for the take of the Covered Species. Several criteria were considered in developing the proposed mitigation plan for this HCP, including:

- The mitigation program should be based on sound biological principles, be practical, and be commensurate with currently anticipated levels of take;
- Mitigation measures should have measurable goals and objectives that allow success to be assessed, and should have flexibility to adjust to higher or lower levels of anticipated take;
- Mitigation measures should be species-specific and should contribute to recovery (i.e., be consistent with recovery plan objectives) and have a net benefit to the species;
- Mitigation may include habitat enhancement or restoration of degraded or former habitats;
- Mitigation measures should be implemented prior to Plan impacts or the approval of this HCP to offset the time lag to achieve a net benefit for the slow growing woody species characteristic of many of the covered plant species.

The mitigation measures described below would meet the mitigation criteria required of HRS Chapter §195D, and would be complementary to other management activities that may be taking place for the benefit of the Covered Species. Over the term of the ITL, mitigation measures may be subject to modification in cooperation with the ESRC (*and in accordance with the Amendment procedures described in Section 7.1 of this HCP*) depending on the measured levels of take and the mitigation measures implemented.

6.1 MITIGATION LOCATIONS

Our main approach for mitigating the take of Covered Species in the Plan Area is through the management of conservation units, which includes large exclosures and small exclosures. Table 6.1 summarizes the existing and proposed exclosures, their sizes, and appropriate Covered Species to be planted in each exclosure. See Figure 4.1 for a map of both current and proposed exclosures. In general, exclosures greater than 100 acres allow for natural regeneration of forest and shrub land species within the exclosure, and may potentially provide a seedbank for adjacent areas. The unfenced exclosures outlined in the Pu‘u Wa‘awa‘a Management Plan and in this HCP target areas to provide protection for relatively good quality remnant dryland forest, mesic forest, and shrub land that are currently not under protection. Larger units allow for the restoration of ecological functions of natural communities and can serve as corridors or refugia for native wildlife and insects. However, larger units also have their limitations, including being more prone to ungulate ingress, which is more difficult to detect with larger fence lines, require larger fuelbreaks and weed management, and there may be a greater chance of damage to fence lines from tree falls or seismic activity.

In general, the following management practices will be effectively implemented within conservation areas and large exclosures:

- Management in conservation units will address not only listed plant species but also their more common and locally rare native community members. The potential benefits of community level restoration include creating habitat for native Hawaiian birds and insect pollinators (thereby potentially encouraging the pollination and dispersal of some plant species), and creating an assemblage of trees that allows for more contiguous habitat to facilitate gene flow between populations.
- Upon the completion of fence construction, ungulates will be removed following ungulate control methods as outlined in State of Hawai‘i Technical Report No. 07-01, *Review of Methods and Approach for Control of Non-native Ungulates in Hawai‘i* (DLNR 2007). Ungulate removal will depend on size and location of the exclosure and will include public hunting, animal drives, and if necessary, staff removal.
- Strict sanitation guidelines will be followed to prevent new introductions of invasive species. Weed infestations shall be addressed on a case by case basis, with follow-up if needed. As native communities become more vigorous, invasive species cover and treatment should decrease over time. Strict sanitation guidelines will be followed to prevent new introductions of invasive species.
- Research into factors beneficial to community restoration will be encouraged, including: ungulate ecology and behavior, pollination, phenology, mycorrhizae, dispersal, seed ecology, and macro invertebrates, etc.
- Education and outreach will be encouraged, and access to areas appropriate for traditional use of the area by native Hawaiians will be encouraged, in a way that minimizes negative impacts and maximizes appreciation for these resources. Direct access should be regulated to minimize impact to the species, as well as to minimize accidental introduction or re-introduction of invasive species.

6.1.1 Current Enclosures for Outplanting

Pu‘u Wa‘awa‘a Forest Bird Sanctuary (FBS) – 3,744 acres

Currently, the 3,744-acre Forest Bird Sanctuary Unit contains remnant mesic forest, high elevation native shrub land, and numerous sensitive lava tube ecosystems above 1,158 m elevation. The FBS contains an exceptional diversity of native flora and fauna, as well as some of the best remaining habitat for these species. The FBS supports several species of rare plants including two species covered under the HCP as well as offers opportunities for the re-establishment of a number of the of Covered Species now extirpated from the area.

Covered plant species currently found within this enclosure include the ‘Aiea and *A. peruvianum*. Species of concern that occur within this unit and were mapped during surveys include ‘Akoko (*Euphorbia olowaluana*), Mau‘u lā‘ili (*Sisyrinchium acre*), and ‘Ōhelo papa (*Fragaria chiloensis* var. *sandwicensis*). Opportunities exist for creating new populations of the following covered plant species: *Asplenium peruvianum*, Pōpolo kū mai, ‘Aiea, *Stenogyne angustifolia*, Hawaiian Catchfly, Po‘e, and both species of A‘e (*Z. dipetalum* var. *tomentosum* and *Z. hawaiiensis*).

Waihou I – 211 acres

Waihou forest was once transitional woodland that connected the moist montane mesic and lowland dry forests. Though highly degraded, it is still an important conservation link between the two forest types. At the turn of the last century, this mixed woodland was dominated by ‘Ōhi‘a, Koa, Māmane, Naio, and ‘Akoko. Vegetation was said to be so thick in places that it was almost impossible to pass through the forest (Rock 1913). Today, Waihou forest consists of remnant patches of native vegetation. There is good potential for recovery in this area, which includes some of the best mixed woodland remaining at Pu‘u Wa‘awa‘a. There is still substantial native tree cover and readily regenerating Koa, Māmane, and Naio, especially after seasonal rains.

Covered Plant Species currently found within the enclosure include A‘e (*Zanthoxylum dipetalum* var. *tomentosum*) and ‘Aiea. Species of concern include ‘Akoko (*Euphorbia olowaluana*), and ‘Anunu (*Sicyos macrophyllus*). Opportunities exist for creating new populations of the following covered plant species: ‘Aiea, Po‘e, Hawaiian Catchfly, Pōpolo kū mai, *S. angustifolia*, and both species of A‘e (*Z. dipetalum* var. *tomentosum* and *Z. hawaiiense*).

Pāpala – 81 acres

The Pu‘u Wa‘awa‘a cinder cone was formed 100,000 years ago. The cone is characterized by its many furrows created by rainfall run off that provide shade for a number of endangered and threatened species. It is the largest cinder cone on the island, and contains remnants of an uncommon forest type dominated by Olopua (*Nestegis sandwicensis*) and Mānele (*Sapindus saponaria*). The Hawaiian soapberry tree (Mānele) is only known on Hawai‘i island from Kīpuka Puauulu and Kīpuka Ki in Hawai‘i Volcanoes National Park and from one region at Pu‘u Wa‘awa‘a. Though this species is not considered rare, it is uncommon and deserves protection at this locale.

No Covered Species were found during HCP surveys within the Pāpala unit; however, a number of species have been outplanted in the unit, including: ‘Aiea, *Neraudia ovata*, Pōpolo kū mai, and A‘e (*Zanthoxylum dipetalum* var. *tomentosum*). This unit has potential for outplanting of

additional Covered Species including: Hala pepe, Hawaiian Catchfly, *Stenogyne angustifolia*, A'e (*Zanthoxylum dipetalum* var. *tomentosum*), and A'e (*Zanthoxylum hawaiiensis*).

Kīpuka Oweowe – Two fenced units totaling 26 acres

This forest is dominated by Lama, but also contains the endangered Kauila, Hala pepe, and 'Aiea trees. This area contains habitat that is important for the federally listed Blackburn's sphinx moth (*Manduca blackburni*).

Covered Species that have been outplanted in this unit include: Kauila, Hala pepe, 'Aiea, Uhiuhi, Pōpolo kū mai, and *Silene lanceolata*.

Hauaina – 49 acres

The overall objective within this unit is dryland forest restoration with special consideration for Nēnē habitat improvement. This enclosure also has potential as a reintroduction site for the following species: Kauila, Koki'o, Hala pepe, Uhiuhi, 'Aiea, A'e (*Zanthoxylum dipetalum* var. *tomentosum*), Ma'o hau hele, *Neraudia ovata*, and Pōpolo kū mai. Other potential actions include upgrading the perimeter fence from small mammal exclusion to rodent-proof; a floating island over the shallow end of the reservoir for water bird refuge, surface area reduction, and native shrub planting.

Po'ohoho'o – 29 acres

The Po'ohoho'o cinder cone is at an elevation of 3,800 ft located just below the Forest Bird Sanctuary. In the 1960's, under a previous lessee, this site was chosen for a water reservoir. Two rubber lined reservoirs were constructed along with a surface rain catchment. Currently, only a small component of the original catchment/storage system remains functional. There are plans to decommission this reservoir and to repair the liner of the smaller reservoir. Po'ohoho'o is an avoidance and minimization enclosure for 'Aiea, as well as a potential outplanting site for additional covered species, including: *N. Ovata*, Po'e, Hawaiian Catchfly, Pōpolo kū mai, *S. angustifolia*, and both species of A'e (*Z. dipetalum* var. *tomentosum* and *Z. hawaiiense*).

6.1.2 Future Exclosures for Outplanting¹⁹

These proposed exclosures were described in the Section 4.3 Avoidance and Minimization and when constructed will be available for outplanting Covered Species.

Waihou II – 202 acres

An additional 202 acres of remnant forest and endangered species habitat adjacent to the currently fenced Waihou forest will be fenced. The expansion of the Waihou forest fence will greatly increase the amount of protected area in which to recover both existing and recently extirpated endangered plant populations. This area is considered a priority because it contains numerous individuals of the endangered ‘Aiea, at least two individuals of the endangered A‘e tree (*Zanthoxylum dipetalum* var. *tomentosum*), and the SOCs, ‘Akoko (*Euphorbia olowaluana*), and *Melicope hawaiiensis*. Species appropriate for outplanting in this unit include: ‘Aiea, *N. ovata*, Hala pepe, Po‘e, Hawaiian Catchfly, *S. angustifolia*, and Pōpolo kū mai.

Henahena – 731 acres

This fenced unit will provide protection to remaining ‘Ōhi‘a forest and the fragile lava tube ecosystems that occur underneath this forest type. Forests of ‘Ōhi‘a predominate in this area. The Henahena region contains numerous sandalwood trees (‘Iliahi) and numerous endangered ‘Aiea trees which are host to the endangered Blackburn’s sphinx moth (*Manduca blackburni*). Additionally this area contains lava tube systems that merit protection. Species appropriate for outplanting in this unit include: ‘Aiea, *N. ovata*, both species of A‘e (*Z. dipetalum* var. *tomentosum* and *Z. hawaiiense*), Po‘e, Hawaiian Catchfly, *S. angustifolia*, and Pōpolo kū mai.

Kauila Hala pepe – 375 acres

This unit will protect the remaining highest quality Kauila and Hala pepe dominated forest within the Plan Area. Reduction of fuel loads around and inside the fenced exclosure will be done using a combination of cattle (outside exclosure), bulldozers, weed eaters, and herbicide. Species appropriate for outplanting in this unit include: Uhiuhi, Kauila, *H. haplostachya*, Ma‘o hau hele, Koki‘o, *N. ovata*, ‘Aiea, Po‘e, *S. lanceolata*, Pōpolo kū mai, *S. angustifolia*, and A‘e (*Z. hawaiiense*).

Lama Koki‘o – 382 acres

This forested area dominated by Lama on old substrate that contains the last remaining wild Koki‘o (*Kokia drynarioides*) trees. This forest type is similar to the Kauila Hala pepe exclosure but has Lama as a co-dominant in the overstory. Species appropriate for outplanting in this unit include: Uhiuhi, Kauila, Honohono, Ma‘o hau hele, Koki‘o, *N. ovata*, ‘Aiea, Po‘e, *S. lanceolata*, Pōpolo kū mai, *S. angustifolia*, and A‘e (*Z. hawaiiense*).

Anahulu I – 255 acres and Anahulu II – 124 acres

This area contains some of the best remaining dry forest shrubland in the upper Pu‘u Anahulu region. Pu‘u Anahulu has been plagued by fires in recent years resulting in a drastically altered landscape. Without management actions including fencing to protect plants from ungulates, fire control, and invasive species management, this area will likely burn in the future resulting in the loss of many species including: A‘e (*Z. hawaiiensis*), Hawaiian Catchfly, *N. ovata*, and

¹⁹ Acreage for proposed exclosures is estimated and may change in the future based on fence-line ground surveys.

S. angustifolia. Species appropriate for outplanting in these units include: *A. peruvianum*, *H. haplostachya*, ‘Aiea, Po‘e, and Pōpolo kū mai.

Zanthoxylum II– 815 acres

This area contains the highest concentration and largest population of A‘e (*Zanthoxylum hawaiiensis*) in the area. Species appropriate for outplanting in this unit include: Hawaiian Catchfly, *N. ovata*, Pōpolo kū mai, and *S. angustifolia*.

‘Aiea– 291 acres

A concentration of the endangered ‘Aiea that provides important habitat for the endangered Blackburn’s sphinx moth (*Manduca blackburni*) will be fenced. This unit will enclose more than 30 ‘Aiea trees and allow for systematic collection of seed from as many individuals as possible for outplanting in the Waihou enclosure. This fence will ensure the long-term survival of these rare trees that are being adversely affected by ungulates, invasive grasses, and insects. The forest here is dominated by ‘Ōhi‘a, Koa, Māmane, Naio and the SOC ‘Akoko. Species appropriate for outplanting in this unit include: ‘Aiea, Po‘e, Hawaiian Catchfly, Pōpolo kū mai, *S. angustifolia*, and both species of A‘e.

Boundary Kīpuka – 42 acres

This unit will protect a portion of a kīpuka that is surrounded by lava flows from Hualālai. It is dominated by Lama and may contain the endangered tree species Kauila, ‘Aiea, and Hala pepe (see description of Lama/Kauila forest above). This area also contains important habitat for the endangered Blackburn’s sphinx moth (*Manduca blackburni*). Hualālai Ranch owns a portion of this kīpuka (although the fenced area will be restricted to state lands). Its isolation may make it a prime area for restoration as it has the Ka‘ūpūlehu lava flow as a natural fuelbreak on one side. Species appropriate for outplanting in this unit include: Kauila, Honohono, Ma‘o hau hele, Koki‘o, *N. ovata*, ‘Aiea, Hala pepe, Po‘e, Hawaiian Catchfly, Pōpolo kū mai, *S. angustifolia*, and A‘e (*Z. hawaiiense*).

Stenogyne– 10 acres

This area contains some of the highest concentrations of *Stenogyne angustifolia* in the Plan Area. Species appropriate for outplanting in this unit include: Honohono, ‘Aiea, Hala pepe, Po‘e, Hawaiian Catchfly, *N. ovata*, Pōpolo kū mai, and A‘e (*Z. dipetalum*).

Solanum Kīpuka – 18 acres

Currently, eight individual plant fences occur in this kīpuka enclosing approximately nine Pōpolo kū mai individuals. The entire kīpuka will be enclosed to further protect these remaining plants. The PTA boundary fence may be utilized as one side of the fencing unit. Species appropriate for outplanting in this unit include: *A. peruvianum*, Honohono, Po‘e, *S. angustifolia*, *N. ovata*, and Hawaiian Catchfly.

Pu‘u Wa‘awa‘a Cone Conservation Area (4 remaining sub-units) – 330 acres

A number of tree species can be found within the furrows of the cinder cone, including Hala pepe and A‘e (*Zanthoxylum dipetalum* var. *tomentosum*). This area is highly visible and provides a good opportunity for education and outreach to the public. Thirteen of the fifteen Covered Species are appropriate for outplanting on the cinder cone: Uhiuhi, Kauila, Honohono, Koki‘o,

Neraudia ovata, ‘Aiea, Hala pepe, Hawaiian Catchfly, Po‘e, Pōpolo kū mai, *Stenogyne angustifolia*, A‘e (*Zanthoxylum dipetalum*), and A‘e (*Zanthoxylum hawaiiensis*).

Uhiuhi 4 – 22 acres

This unit will protect nine Uhiuhi trees on the makai side of Pu‘u Wa‘awa‘a. The protected Uhiuhi trees within the unit will serve as propagule sources for mitigation outplanting in adjacent areas in the future.

Honohono – 5 acres

This area contains the last known population of Honohono found on state land. The site is also suitable for the potential reintroduction of *Stenogyne angustifolia*, Hawaiian Catchfly, Pōpolo kū mai, and *Neraudia ovata*.

Kileo – 533 acres

This area will protect a section of the oldest geologic kīpuka at Pu‘u Wa‘awa‘a and a unique cave system. Kileo is the oldest geologic area of Pu‘u Wa‘awa‘a containing a Naio, Māmane, and ‘A‘ali‘i woodland (a currently unprotected vegetation type at Pu‘u Wa‘awa‘a). The cave system runs from over 1,829 m elevation through the kīpuka to 1,280 m. Approximately 96 acres of this unit extends into DOFAW-managed lands of Pu‘u Anahulu. Potential species to outplant at this outplanting site include: *Asplenium peruvianum*, Honohono, *Neraudia ovata*, ‘Aiea, Hawaiian Catchfly, Po‘e, Pōpolo kū mai, *Stenogyne angustifolia*, and A‘e (*Zanthoxylum hawaiiensis*).

Pu‘u Loa – 530 acres

This forest is located makai of the highway and is dominated by ‘Ōhi‘a. This unit will protect *in situ* individuals of Kauila, Hala pepe, and Uhiuhi. This forest also contains less common native tree species such as ‘Ala‘a (*Pouteria sandwicensis*) and Maua (*Xylosma hawaiiense*).

Table 6.1 Potential mitigation sites for populations within current and proposed conservation units and exclosures. Species codes are: AspPer = *A. peruvianum*, ChrHaw = *C. hawaiiensis*, ColOpp = *C. oppositifolia*, HapHap = *H. haplostachya*, HibBra = *H. brackenridgei*, KokDry = *K. drynarioides*, MezKav = *M. kawaiense*, NerOva = *N. ovata*, NotBre = *N. breviflorum*, PorScl = *P. sclerocarpa*, SilLan = *S. lanceolata*, SolInc = *S. incompletum*, ZanDip = *Z. dipetalum*, ZanHaw = *Z. hawaiiensis*.

	Size (acres)	Asp Per	Chr Haw	Col Opp	Hap Hap	Hib Bra	Kok Dry	Mez Kav	Ner Ova	Not Bre	Por Scl	Sil Lan	Sol Inc	Ste Ang	Zan Dip	Zan Haw	# Species /Unit
Current Units																	
FBS	3,744	1								1	1	1	1	1	1	1	8
Po'ohoho'o	29								1	1	1	1	1	1	1	1	8
Waihou I	211		1						1	1	1	1	1	1	1	1	9
Kīpuka Oweowe	26		1	1	1	1	1	1	1	1	1	1	1	1		1	13
Hauaina	49		1	1	1	1	1	1	1	1	1	1	1	1		1	13
Uhiuhi 1	13		1	1	1	1	1	1	1	1	1	1					10
Zanthoxylum I	7				1				1	1	1	1	1	1		1	8
Neraudia	12				1				1	1	1	1	1	1		1	8
Proposed Units																	
'Aiea	291		1						1	1	1	1	1	1	1	1	9
Waihou II	202		1						1	1	1	1	1	1	1	1	9
Henahena	731								1	1	1	1	1	1	1	1	8
Kauila Hala pepe	375		1	1	1	1	1	1	1	1	1	1	1	1		1	13
S. Kīpuka	42		1	1	1	1	1	1	1	1	1	1	1	1		1	13
Lama Koki'o	382		1	1	1	1	1	1	1	1	1	1	1	1		1	13
Pu'u Loa	530		1	1	1	1	1	1	1	1	1	1				1	11
Uhiuhi 4	22		1	1	1	1		1	1	1	1	1					9
Anahulu I	255	1			1				1	1	1	1	1	1		1	9
Anahulu II	124	1			1				1	1	1	1	1	1		1	9
Zanthoxylum II	815	1			1				1	1	1	1	1	1			8
Stenogyne	10				1				1	1	1	1	1	1		1	8
Honohono	5										1		1	1			3
Solanum Kīpuka	18	1			1				1	1	1	1	1	1		1	9
PWW CCA	330		1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Kileo	533	1			1				1	1	1	1	1	1		1	9

6.2 OFF-SETTING TAKE PRIOR TO HCP APPROVAL

DOFAW has already begun outplanting to offset take for the covered plant species described in this HCP. See Table 6.2 for a list of Covered Species, the number of each species outplanted, and their general locations. DOFAW will be subtracting the number of surviving, mature, reproducing individuals from their anticipated take in order to substantiate a net benefit for each Covered Species.

Table 6.2 Outplanted Covered Species from 2000 to 2014. Species codes are: ColOpp = *C. oppositifolia*, HapHap = *H. haplostachya*, HibBra = *H. brackenridgei*, KokDry = *K. drynarioides*, MezKav = *M. kavaïense*, NerOva = *N. ovata*, NotBre = *N. breviflorum*, ChrHaw = *C. hawaiiensis*, ZanDip = *Z. dipetalum*.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
CHRHAW			24	5	57		8				47	123		24	319	607
HAPHAP								2								2
HIBBRA	30	5	5		93		7	31	6	1	1	21	4			204
KOKDRY	8	2	15		12				23	37	9	162	209	77	42	596
MEZKAV	6	2		6	1		25		3		39	87	37	17	207	430
NEROVA			11							15		4				30
NOTBRE	20	2	119	55	176	40	131		22		2	3		39	68	677
STEANG										16						16
ZANDIP			2	10	1		2			14	7					36
Total	86	47	194	76	340	40	179	33	54	83	106	401	88	203	946	3,039

6.3 SPECIES SPECIFIC MANAGEMENT GOALS

Each individual Covered Species has a mitigation goal based on take estimates and avoidance and minimization strategies. Goals for mitigation for each individual Covered Species are consistent with their associated approved federal recovery plan. Exclosure descriptions provide further detail on exclosure size, habitat type, and species composition. Whenever possible, mitigation exclosures are designed to provide mitigation opportunities for multiple species to increase management efficiency and benefit. Table 6.1 summarizes take estimates, avoidance and minimization strategies, and mitigation goals for each of the Covered Species.

6.3.1 *Asplenium peruvianum var. insulare*

1. DOFAW will maintain *in situ* populations through fencing, monitoring, maintenance, and fire protection (*as described in the Avoidance and Minimization Section 4.3*).
2. DOFAW will propagate, as much as is feasible, complete genetic representation through spores from the known populations in the Plan Area. These plants will be used to maintain genetic representation of stock and will provide stock for outplanting purposes. This species is currently in propagation at Volcano Rare Plant Facility. Seed and propagule collection will be done following HRPRG recommendations (*see Appendix E*).
3. **Mitigation goal:** As discussed in Section 5.3.1, a take estimate is difficult to calculate for this species as it occurs in lava tubes and cave openings. The occurrence and location of this habitat type has not been mapped within the Plan Area. Because of this gap in knowledge, we defer to the species stabilization goals defined in the recovery plan (USFWS 1998b) and defined in Section 5.3.4. DOFAW will create and maintain **three populations of 50 individuals** each within fenced suitable habitat types. Table 6.3 lists the potentially suitable outplanting sites. Priority will be given to those sites already fenced.
4. **Loss of recruitment mitigation:** DOFAW will create and maintain **one additional population of 50 individuals** (following stabilization criteria) which will be created to mitigate for the potential loss of recruitment for those individuals outside of exclosures. Should values calculated from monitoring data exceed those put forth by the stabilization criteria, those values will be added to this mitigation goal.
5. **Net benefit goal:** In effort to provide net benefit to Covered Species beyond replacement mitigation, DOFAW will create **one additional population of 50 individuals** following species stabilization guidelines (USFWS 1998b).
6. **Total Mitigation Goals:** In sum, DOFAW will create 5 populations with 50 mature and reproductive individuals (**for a total of 250 individuals**) within a population that are either a) in separate units, or b) at least 1000 m apart.

Table 6.3 Known *in situ* populations and potential reintroduction sites for *A. peruvianum* var. *insulare*. Exclosures in bold contain extant population(s). All other (non-bold) exclosures are potential sites for reintroduction.

Potential Exclosures	Fenced	Management Type	# of Individuals	Unit Size (acres)
FBS Unit	Yes	Avoidance/minimization	45	3,744
Anahulu I	No	Mitigation		255
Anahulu II	No	Mitigation		124
Zanthoxylum II	No	Mitigation		815
Solanum Kīpuka	No	Mitigation		18
Kileo	No	Mitigation		533

6.3.2 Hala pepe (*Chrysodracon hawaiiensis*)

1. DOFAW will maintain *in situ* populations through fencing, monitoring, maintenance, and fire protection (*as described in Section 4.3 Avoidance and Minimization*).
2. DOFAW will propagate a complete genetic representation (as is feasible) through seeds from the known Pu‘u Wa‘awa‘a and Pu‘u Anahulu populations. These plants will be used to maintain genetic representation of stock and will provide stock for outplanting purposes. This species is currently in propagation at Volcano Rare Plant Facility and the DOFAW Tree Nursery in Kamuela. Seed and propagule collection will be done following HRPRG (*see Appendix E*).
3. **Mitigation goal:** DOFAW will create and maintain a minimum of **three populations** within fenced suitable habitat types to total the take estimate (**331 individuals**). Table 6.1 lists the potentially suitable outplanting sites. Priority will be given to those sites already fenced.
4. **Loss of recruitment mitigation:** DOFAW will create and maintain **one additional population of 25 individuals** (following stabilization criteria defined in the recovery plan (USFWS 1998a) which will be created to mitigate for the potential loss of recruitment for those individuals outside of exclosures. Should values calculated from monitoring data exceed those put forth by the stabilization criteria, those values will be added to this mitigation goal.
5. **Net benefit goal:** In effort to provide net benefit to Covered Species beyond replacement mitigation, DOFAW will create **one additional population of 25 individuals** following species stabilization guidelines (USFWS 1998a).
6. **Total Mitigation Goal:** In sum, DOFAW will create a minimum of 5 populations with a minimum of 25 mature and reproductive individuals within each population (**for a total of 381 number of individuals**) that are either a) in separate units, or b) at least 1000 m apart.

Table 6.4 Known *in situ* populations and potential reintroduction sites for Hala pepe.

Exclosure	Fenced	Management Type	# of Individuals	Unit Size (acre)
Kauila Hala pepe	No	Avoidance/minimization	148	375
Pu‘u Loa	No	Avoidance/minimization	30	530
Lama Koki‘o	No	Avoidance/minimization	6	382
Hala pepe	No	Avoidance/minimization	62	92
Kīpuka Oweowe	Yes	Avoidance/minimization	1	26
Waihou I	Yes	Mitigation		211
Hauaina	Yes	Mitigation		49
Uhiuhi 1	Yes	Mitigation		13
Waihou II	No	Mitigation		202
Boundary Kīpuka	No	Mitigation		42
Uhiuhi 4	No	Mitigation		22

6.3.3 Kauila (*Colubrina oppositifolia*)

1. DOFAW will maintain *in situ* populations through fencing, monitoring, maintenance, and fire protection (*as described in Section 4.3 Avoidance and Minimization*).
2. DOFAW will propagate a complete genetic representation (as is feasible) through seeds and cuttings from the known Pu‘u Wa‘awa ‘a populations. These plants will be used to maintain genetic representation of stock and will provide stock for outplanting purposes. This species is currently in propagation at Volcano Rare Plant Facility. Seed and propagule collection will be done following HRPRG recommendations (*see Appendix E*).
3. **Mitigation goal:** DOFAW will create and maintain **three populations** within fenced suitable habitat types to total the take estimate (**805 individuals**). Table 6.5 lists the potentially suitable outplanting sites. Priority will be given to those sites already fenced.
4. **Loss of recruitment mitigation:** DOFAW will create and maintain **one additional population of 25 individuals** following stabilization criteria defined in the recovery plan (USFWS 1996b) will be created to mitigate for the potential loss of recruitment for those individuals outside of exclosures. Should values calculated from monitoring data exceed those put forth by the stabilization criteria, those values will be added to this mitigation goal.
5. **Net benefit goal:** In an effort to provide net benefit to Covered Species beyond replacement mitigation, DOFAW will create **one additional population of 25 individuals** following species stabilization guidelines (USFWS 1996b).
6. **Total Mitigation Goal:** In sum, DOFAW will create a minimum of 5 populations with a minimum of 25 mature and reproductive individuals within each population (**for a total of 855 number of individuals**) that are either a) in separate units, or b) at least 1000 m apart.

Table 6.5 Known *in situ* populations and potential reintroduction sites for Kauila. Bold units contain extant population(s).

Potential Exclosures	Fenced	Management Type	# of Individuals	Unit Size (acres)
Pu‘u Loa	No	Avoidance/minimization	5	530
Kauila Hala pepe	No	Avoidance/minimization	643	375
Kīpuka Oweowe	Yes	Mitigation		26
Boundary Kīpuka	No	Mitigation		42
Lama Koki‘o	No	Mitigation	33	382
PWW CCA	No	Mitigation		330
Uhiuhi 4	No	Mitigation		22

6.3.4 Honohono (*Haplostachys haplostachya*)

1. DOFAW will maintain *in situ* populations through fencing, monitoring, maintenance, and fire protection (*as described in the Section 4.3 Avoidance and Minimization*).
2. DOFAW will propagate a complete genetic representation (as is feasible) through seeds and cuttings from the known Keamuku Pu‘u Anahulu population. These plants will be used to maintain genetic representation of stock and will provide stock for outplanting purposes. This species is currently in propagation at Volcano Rare Plant Facility. Seed and propagule collection will be done following HRPRG recommendations (*see Appendix E*).
3. **Mitigation goal:** DOFAW will create and maintain a minimum of **three populations** within fenced suitable habitat types to total the take estimate (**796 individuals**). Table 6.6 lists the potentially suitable outplanting sites. Priority will be given to those sites already fenced.
4. **Loss of recruitment mitigation: DOFAW will create and maintain one additional population of 50 individuals** following stabilization criteria defined in the recovery plan (USFWS 1993) will be created to mitigate for the potential loss of recruitment for those individuals outside of exclosures. Should values calculated from monitoring data exceed those put forth by the stabilization criteria, those values will be added to this mitigation goal.
5. **Net benefit goal:** In an effort to provide net benefit to Covered Species beyond replacement mitigation, DOFAW will create **one additional population of 50 individuals** following species stabilization guidelines (USFWS 1993).
6. **Total Mitigation Goal:** In sum, DOFAW will create a minimum of 5 populations with a minimum of 50 mature and reproductive individuals within each population (**for a total of 896 number of individuals**) that are either a) in separate units, or b) at least 1000 m apart.

Table 6.6 Known *in situ* populations and potential reintroduction sites for Honohono. Units in bold contain extant population(s).

Potential Exclosures	Fenced	Management Type	# of Individuals	Unit Size (acres)
Honohono	No	Avoidance/minimization	80	5
Anahulu I	No	Mitigation		255
Anahulu II	No	Mitigation		124
Stenogyne	No	Mitigation		10
Kauila Hala pepe	No	Mitigation		375
Boundary Kīpuka	No	Mitigation		42
Pu‘u Loa	No	Mitigation		530
Uhiuhi 4	No	Mitigation		22
Solanum Kīpuka	No	Mitigation		18
Kileo	No	Mitigation		533

6.3.5 Ma‘o hau hele (*Hibiscus brackenridgei* ssp. *brackenridgei*)

1. DOFAW will maintain *in situ* populations through fencing, monitoring, maintenance, and fire protection (as described in Section 4.3 Avoidance and Minimization).
2. DOFAW will propagate a complete genetic representation (as is feasible) through seeds and cuttings from the known Pu‘u Wa‘awa ‘a populations. These plants will be used to maintain genetic representation of stock and will provide stock for outplanting purposes. This species is currently in propagation at Volcano Rare Plant Facility and the DOFAW Tree Nursery in Kamuela. Seed and propagule collection will be done following HRPRG recommendations (see Appendix E).
3. **Mitigation goal:** The take estimate for this species is 58 individuals because a population made up of such a small number of individuals is likely too small to become self-sustaining over time, we defer to the species stabilization guidelines. Based on species stabilization goals defined in the recovery plan (USFWS 1999) and defined in Section 5.3.4. DOFAW will create and maintain a minimum of **three populations of 50 individuals** within fenced suitable habitat types. Table 6.7 lists the potentially suitable outplanting sites. Priority will be given to those sites already fenced.
4. **Loss of recruitment mitigation:** DOFAW will create and maintain **one additional population of 50 individuals** (following stabilization criteria) will be created to mitigate for the potential loss of recruitment for those individuals outside of exclosures. Should values calculated from monitoring data exceed those put forth by the stabilization criteria, those values will be added to this mitigation goal.
5. **Net benefit goal:** In an effort to provide net benefit to Covered Species beyond replacement mitigation, DOFAW will create **one additional population of 50 individuals** following species stabilization guidelines (USFWS 1999).
6. **Total Mitigation Goal:** In sum, DOFAW will create 5 populations with a minimum of 50 mature and reproductive individuals within each population (**for a total of 250 individuals**) that are either a) in separate units, or b) at least 1000 m apart.

Table 6.7 Known *in situ* populations and potential reintroduction sites for Ma‘o hau hele. Bold units contain extant population(s).

Potential Exclosures	Fenced	Management Type	# of Individuals	Unit Size (acres)
Hib. Brackenridgei	Yes	Avoidance/minimization	65	1
Kīpuka Oweowe	Yes	Mitigation		26
Hauaina	Yes	Mitigation		49
Uhiuhi 1	Yes	Mitigation		13
Kauila Hala pepe	No	Mitigation		375
Boundary Kīpuka	No	Mitigation		42
Lama Koki‘o	No	Mitigation		382
Pu‘u Loa	No	Mitigation		530
Uhiuhi 4	No	Mitigation		22

6.3.6 Koki‘o (*Kokia drynarioides*)

1. DOFAW will maintain outplanted individuals through maintenance of fences, monitoring, and fire protection (*as described in Section 4.3 Avoidance and Minimization*).
2. The four individuals documented during HCP surveys occur within small exclosures in the Plan Area. DOFAW will propagate a (as feasible) complete genetic representation through seeds and cuttings from plant stock that has been collected over the years from the few remaining Koki‘o at Pu‘u Wa‘awa‘a. These plants will be used to maintain genetic representation of stock and will provide stock for outplanting purposes. This species is currently in propagation at Volcano Rare Plant Facility and the DOFAW Tree Nursery in Kamuela. Seed and propagule collection will be done following HRPRG guidelines (*see Appendix E*).
3. **Mitigation goal:** The take estimate for this species is one individual. We defer to the species stabilization guidelines for our mitigation goals. Based on species stabilization goals defined in the recovery plan (USFWS 1994) and defined in Section 5.3.4, DOFAW will create and maintain **three populations of 100 individuals** each within fenced suitable habitat types. Table 6.8 lists the potentially suitable outplanting sites. Priority will be given to those sites already fenced.
4. **Loss of recruitment mitigation:** DOFAW will create and maintain **one additional population of 100 individuals** (following stabilization criteria) will be created to mitigate for the potential loss of recruitment for those individuals outside of exclosures. Should values calculated from monitoring data exceed those put forth by the stabilization criteria, those values will be added to this mitigation goal.
5. **Net benefit goal:** In an effort to provide net benefit to Covered Species beyond replacement mitigation, DOFAW will create **one additional population of 100 individuals** following species stabilization guidelines (USFWS 1994).
6. **Total Mitigation Goals:** In sum, DOFAW will create 5 populations with a minimum of 100 mature and reproductive individuals (**for a total of 500 individuals**) within each population that are either a) in separate units, or b) at least 1000 m apart.

Table 6.8 Known *in situ* populations and potential reintroduction sites for for Koki‘o.

Potential Enclosures	Fenced	Management Type	# of Individuals	Unit Size (acre)
Kīpuka Oweowe	Yes	Mitigation		26
Koki‘o 1	Yes	Propagule	2	>1
Koki‘o 2	Yes	Propagule	2	>1
Waihou I	Yes	Mitigation		211
Hauaina	Yes	Mitigation		49
Uhiuhi 1	Yes	Mitigation		13
Kauila Hala pepe	No	Mitigation		375
Boundary Kīpuka	No	Mitigation		42
Lama Koki‘o ²⁰	No	Mitigation	4	382
Pu‘u Loa	No	Mitigation		530

²⁰ Koki‘o 1 and Koki‘o 2 will be incorporated into the Lama Koki‘o enclosure.

6.3.7 Uhiuhi (*Mezoneuron kawaiense*)

1. DOFAW will maintain *in situ* populations through fencing, monitoring, maintenance, and fire protection (*as described in Section 4.3 Avoidance and Minimization*).
2. DOFAW will propagate a complete genetic representation as much as is feasible, through seeds and air layers from the known makai Pu‘u Wa‘awa‘a populations. These plants will be used to maintain genetic representation of stock and will provide stock for outplanting purposes. This species is currently in propagation at Volcano Rare Plant Facility and the DOFAW tree nursery in Kamuela. Seed and propagule collection will be done following HRPRG recommendations (*see Appendix E*).
3. **Mitigation goal:** DOFAW will create and maintain a minimum of **three populations** within fenced suitable habitat types to total the take estimate (**144 individuals**). Table 6.9 lists the potentially suitable outplanting sites. Priority will be given to those sites already fenced.
4. **Loss of recruitment mitigation: DOFAW will create and maintain one additional population of 50 individuals**, following stabilization criteria defined in the recovery plan (USFWS 1994), which will be created to mitigate for the potential loss of recruitment for those individuals outside of exclosures. Should values calculated from monitoring data exceed those put forth by the stabilization criteria, those values will be added to this mitigation goal.
5. **Net benefit goal:** In an effort to provide net benefit to Covered Species beyond replacement mitigation, DOFAW will create **one additional population of 50 individuals** following species stabilization guidelines (USFWS 1994).
6. **Total Mitigation Goal:** In sum, DOFAW will create a minimum of 5 populations with a minimum of 50 mature and reproductive individuals within each population (**for a total of 244 individuals**) that are either a) in separate units, or b) at least 1000 m apart.

Table 6.9 Known *in situ* populations and potential reintroduction sites for Uhiuhi. Bold units contain extant population(s).

Potential Exclosures	Fenced	Management Type	# of Individuals	Unit Size (acres)
Uhiuhi 4	No	Avoidance/minimization	9	22
Pu‘u Loa	Yes	Avoidance/minimization	2	3
Uhiuhi 3	Yes	Propagule		1
Kīpuka Oweowe	Yes	Mitigation		26
Kauila Hala pepe	No	Mitigation		375
Lama Koki‘o	No	Mitigation		382
Pu‘u Loa	No	Mitigation		530

6.3.8 *Neraudia ovata*

1. DOFAW will maintain *in situ* populations through fencing, monitoring, maintenance, and fire protection (*as described in Section 4.3 Avoidance and Minimization*).
2. DOFAW will propagate a (as feasible) complete genetic representation through seeds and cuttings from the known Pu‘u Anahulu individuals. These plants will be used to maintain genetic representation of stock and will provide stock for outplanting purposes. This species is currently in propagation at Volcano Rare Plant Facility. Seed and propagule collection will be done following HRPRG (*see Appendix E*).
3. **Mitigation goal:** The take estimate for this species is 29 individuals, because a population made up of such a small number of individuals is likely too small to become self-sustaining over time, we defer to the species stabilization guidelines. Based on species stabilization goals defined in the recovery plan (USFWS 1998a), and defined in Section 5.3.4, DOFAW will create and maintain **three populations of 100** individuals each within fenced suitable habitat types. Table 6.10 lists the potentially suitable outplanting sites. Priority will be given to those sites already fenced.
4. **Loss of recruitment mitigation:** DOFAW will create and maintain **one additional population of 100 individuals** (following stabilization criteria) will be created to mitigate for the potential loss of recruitment for those individuals outside of exclosures. Should values calculated from monitoring data exceed those put forth by the stabilization criteria, those values will be added to this mitigation goal.
5. **Net benefit goal:** In an effort to provide net benefit to Covered Species beyond replacement mitigation, DOFAW will create **one additional population of 100 individuals** following species stabilization guidelines (USFWS 1998a).
6. **Total Mitigation Goals:** In sum, DOFAW will create 5 populations with a minimum of 100 mature and reproductive individuals within each population (**for a total of 500 individuals**) that are either a) in separate units, or b) at least 1000 m apart.

Table 6.10 Known *in situ* populations and potential reintroduction sites for for *Neraudia ovata*.

Exclosure	Fenced	Management Type	# of Individuals	Unit Size (acre)
NerOva 1	Yes	Propagule	2	>1
NerOva 2	Yes	Propagule	1	>1
Neraudia Unit	Yes	Propagule?	?	12
Anahulu I	No	Avoidance/minimization	6	255
Anahulu II	No	Avoidance/minimization	3	124
Kīpuka Oweowe	Yes	Mitigation		26
Po‘ohoho‘o	Yes	Mitigation		29
PWW CCA	Yes	Mitigation		330
Waihou I	Yes	Mitigation		211
Hauaina	Yes	Mitigation		49
Uhiuhi 1	Yes	Mitigation		13
Zanthoxylum	Yes	Mitigation		7
Waihou II	No	Mitigation		202

Exclosure	Fenced	Management Type	# of Individuals	Unit Size (acre)
Henahena	No	Mitigation		731
Kauila Hala pepe	No	Mitigation		375
Pu'u Loa	No	Mitigation		530
Uhiuhi 4	No	Mitigation		22
Kileo	No	Mitigation		533

6.3.9 ‘Aiea (*Nothocestrum breviflorum*)

1. DOFAW will maintain *in situ* populations through fencing, monitoring, maintenance, and fire protection (as described in Section 4.3 Avoidance and Minimization).
2. DOFAW will propagate a complete genetic representation (as is feasible) through seeds and cuttings from the known Pu‘u Wa‘awa‘a populations. These plants will be used to maintain genetic representation of stock and will provide stock for outplanting purposes. This species is currently in propagation at Volcano Rare Plant Facility and the DOFAW Tree Nursery in Kamuela. Seed and propagule collection will be done following HRPRG recommendations (see Appendix E).
3. **Mitigation goal:** DOFAW will create and maintain **three populations** within fenced suitable habitat types to total the take estimate (**265 individuals**). Table 6.11 lists the potentially suitable outplanting sites. Priority will be given to those sites already fenced.
4. **Loss of recruitment mitigation:** DOFAW will create and maintain **one additional population of 50 individuals** following stabilization criteria defined in the recovery plan (USFWS 1996b) will be created to mitigate for the potential loss of recruitment for those individuals outside of exclosures. Should values calculated from monitoring data exceed those put forth by the stabilization criteria, those values will be added to this mitigation goal.
5. **Net benefit goal:** In an effort to provide net benefit to Covered Species beyond replacement mitigation, DOFAW will create **one additional population of 50 individuals** following species stabilization guidelines (USFWS 1996b).
6. **Total Mitigation Goal:** In sum, DOFAW will create a minimum of 5 populations with a minimum of 50 mature and reproductive individuals within each population (**for a total of 365 individuals**) that are either a) in separate units, or b) at least 1000 m apart.

Table 6.11 Known *in situ* populations and potential reintroduction sites for ‘Aiea.

Exclosure	Fenced	Management Type	# of Individuals	Unit Size (acre)
Henahena	No	Avoidance/minimization	20	731
Kauila Hala pepe	No	Avoidance/minimization	6	375
Kīpuka Oweowe	Yes	Avoidance/minimization	6	26
Po‘ohoho‘o	Yes	Avoidance/minimization	6	29
‘Aiea	Yes- individual fences	Propagule	33	>1
PWW CCA	Yes	Mitigation		330
FBS	Yes	Mitigation	3	3,744
Waihou I	Yes	Mitigation	9	211
Waihou II	No	Mitigation		202
Hauaina	Yes	Mitigation		49
Uhiuhi 1	Yes	Mitigation	1	13
Neraudia	Yes	Mitigation		12
Zanthoxylum	Yes	Mitigation		7
Kauila Hala pepe	No	Mitigation		375

Exclosure	Fenced	Management Type	# of Individuals	Unit Size (acre)
Boundary Kīpuka	No	Mitigation		42
Lama Koki'o	No	Mitigation	16	382
Pu'u Loa	No	Mitigation		530
Uhiuhi 4	No	Mitigation		22
Anahulu I	No	Mitigation		255
Anahulu II	No	Mitigation		124
Zanthoxylum II	No	Mitigation		815
Stenogyne	No	Mitigation		10
Honohono	No	Mitigation		5
Solanum Kīpuka	No	Mitigation		18
PWW CCA	No	Mitigation		330
Kileo	No	Mitigation		533

6.3.10 Po'e (*Portulaca sclerocarpa*)

1. DOFAW will maintain *in situ* populations through fencing, monitoring, maintenance, and fire protection (*as described in Section 4.3 Avoidance and Minimization*).
2. DOFAW will propagate a (as feasible) complete genetic representation from the individual(s) in the Anahulu I unit. These plants will be used to maintain genetic representation of stock and will provide stock for outplanting purposes. This species is currently in propagation at Volcano Rare Plant Facility. Seed and propagule collection will be done following HRPRG recommendations (*see Appendix E*).
3. **Mitigation goal:** As discussed in Section 5.3.1, a take estimate is difficult to calculate for this species as only one individual was found. Because of this gap in knowledge, we defer to the species stabilization goals defined in the recovery plan (USFWS 1996b) and defined in Section 5.3.4. DOFAW will create and maintain **three populations of 50 individuals** each within fenced suitable habitat types. Table 6.12 lists the potentially suitable outplanting sites. Priority will be given to those sites already fenced.
4. **Loss of recruitment mitigation: DOFAW will create and maintain one additional population of 50 individuals** (following stabilization criteria) which will be created to mitigate for the potential loss of recruitment for those individuals outside of exclosures. Should values calculated from monitoring data exceed those put forth by the stabilization criteria, those values will be added to this mitigation goal.
5. **Net benefit goal:** In effort to provide net benefit to Covered Species beyond replacement mitigation, DOFAW will create **one additional population of 50 individuals** following species stabilization guidelines (USFWS 1996b).
6. **Total Outplanting Goals:** In sum, DOFAW will create 5 populations with a minimum of 50 mature and reproductive individuals within each population (**for a total of 250 individuals**) that are either a) in separate units, or b) at least 1000 m apart.

Table 6.12 Known *in situ* populations and potential reintroduction sites for Po‘e. Enclosures in bold contain extant population(s). All other enclosures are potential sites for reintroduction.

Enclosure	Fenced	Management Type	# of Individuals	Unit Size (acre)
Anahulu I	No	Avoidance/minimization	1	255
Henahena	No	Mitigation		731
Kauila Hala pepe	No	Mitigation		375
Kīpuka Oweowe	Yes	Mitigation		22
‘Aiea	No	Mitigation		>1
Po‘ohoho‘o	Yes	Mitigation		29
FBS	Yes	Mitigation		3,744
Waihou I	Yes	Mitigation		211
Waihou II	No	Mitigation		202
Hauaina	Yes	Mitigation		49
Uhiuhi 1	Yes	Mitigation		13
Neraudia	Yes	Mitigation		12
Zanthoxylum	Yes	Mitigation		7
Boundary Kīpuka	No	Mitigation		42
Lama Koki‘o	No	Mitigation		382
Pu‘u Loa	No	Mitigation		530
Uhiuhi 4	No	Mitigation		22
Anahulu II	No	Mitigation		124
Zanthoxylum II	No	Mitigation		815
Stenogyne	No	Mitigation		10
Honohono	No	Mitigation		5
Solanum Kīpuka	No	Mitigation		18
PWW CCA	Partially	Mitigation		330
Kileo	No	Mitigation		533

6.3.11 Hawaiian Catchfly (*Silene lanceolata*)

1. DOFAW will maintain *in situ* populations through fencing, monitoring, maintenance, and fire protection (*as described in Section 4.3 Avoidance and Minimization*).
2. DOFAW will propagate a complete genetic representation (as is feasible) through seeds and cuttings from the known Pu‘u Anahulu populations. These plants will be used to maintain genetic representation of stock and will provide stock for outplanting purposes. This species is currently in propagation at Volcano Rare Plant Facility. Seed and propagule collection will be done following HRPRG (*see Appendix E*).
3. **Mitigation goal:** DOFAW will create and maintain a **minimum of 3 populations** within fenced suitable habitat types to total the take estimate (**1,812 individuals**). Table 6.13 lists the potentially suitable outplanting sites. Priority will be given to those sites already fenced.
4. **Loss of recruitment mitigation:** DOFAW will create and maintain **one additional population of 50 individuals** following stabilization criteria defined in the recovery plan (USFWS 1996c) which will be created to mitigate for the potential loss of recruitment for those individuals outside of exclosures. Should values calculated from monitoring data exceed those of forth by the stabilization criteria, those values will be added to this mitigation goal.
5. **Net benefit goal:** In effort to provide net benefit to Covered Species beyond replacement mitigation, DOFAW will create **one additional population of 50 individuals** following species stabilization guidelines (USFWS 1996c).
6. **Total Mitigation Goal:** In sum, DOFAW will create a minimum of 5 populations with a minimum of 50 mature and reproductive individuals within each population (**for a total of 1,912 individuals**) that are either a) in separate units, or b) at least 1000 m apart.

Table 6.13 Known *in situ* populations and potential reintroduction sites for Hawaiian Catchfly.

Population Unit	Fenced	Management Type	# of Individuals	Unit Size (acre)
Anahulu I	No	Avoidance/minimization	30	255
Kīpuka Oweowe	Yes	Mitigation		26
Waihou I	Yes	Mitigation		211
PWW CCA	Yes	Mitigation		330
Kīpuka Oweowe	Yes	Mitigation		26
Po'ohoho'o	Yes	Mitigation		29
Hauaina	Yes	Mitigation		49
Uhiuhi 1	Yes	Mitigation		13
Zanthoxylum	Yes	Mitigation		7
Neraudia	Yes	Mitigation		12
Waihou II	No	Mitigation		202
Henahena	No	Mitigation		731
Kauila Hala pepe	No	Mitigation		375
Boundary Kīpuka	No	Mitigation		42
Lama Koki'o	No	Mitigation		382
Pu'u Loa	No	Mitigation		530
Uhiuhi 4	No	Mitigation		22
Anahulu II	No	Mitigation		124
Zanthoxylum II	No	Mitigation		815
Stenogyne	No	Mitigation		10
Honohono	No	Mitigation		5
Solanum Kīpuka	No	Mitigation		18
PWW CCA	No	Mitigation		330
Kileo	No	Mitigation		533

6.3.12 Pōpolo kū mai (*Solanum incompletum*)

1. DOFAW will maintain *in situ* populations through fencing, monitoring, maintenance, and fire protection (*as described in Section 4.3 Avoidance and Minimization*).
2. DOFAW will propagate a (as feasible) complete genetic representation through seeds and cuttings from the known Pu‘u Anahulu individuals. These plants will be used to maintain genetic representation of stock and will provide stock for outplanting purposes. This species is currently in propagation at Volcano Rare Plant Facility. Seed and propagule collection will be done following HRPRG (*see Appendix E*).
3. **Mitigation goal:** The take estimate for this species is **87 individuals**. Because a population made up of such a small number of individuals is likely too small to become self-sustaining over time, we defer to the species stabilization goals outlined in the recovery plan (USFWS 1999) and defined in Section 5.3.4, DOFAW will create and maintain a **minimum of three populations of 100 individuals** each within fenced suitable habitat types. Table 6.14 lists the potentially suitable outplanting sites. Priority will be given to those sites already fenced.
4. **Loss of recruitment mitigation:** DOFAW will create and maintain **one additional population of 100 individuals** (following stabilization criteria) which will be created to mitigate for the potential loss of recruitment for those individuals outside of exclosures. Should values calculated from monitoring data exceed those of put forth by the stabilization criteria, those values will be added to this mitigation goal.
5. **Net benefit goal:** In an effort to provide net benefit to Covered Species beyond replacement mitigation, DOFAW will create **one additional population of 100 individuals** following species stabilization guidelines (USFWS 1999).
6. **Total Mitigation Goals:** In sum, DOFAW will create 5 populations with a minimum of 100 mature and reproductive individuals within each population (**for a total of 500 individuals**) that are either a) in separate units, or b) at least 1000 m apart.

Table 6.14 Known *in situ* populations and potential reintroduction sites for Pōpolo kū mai. Exclosures in bold contain extant population(s).

Population Unit	Fenced	Management Type	# of Individuals	Unit Size (acre)
SolInc	8 small units	Avoidance/minimization	13	18
Kīpuka Oweowe	Yes	Mitigation		26
Pāpala	Yes	Mitigation		74
Po'ohoho'ō	Yes	Mitigation		29
Hauaina	Yes	Mitigation		49
Zanthoxylum	Yes	Mitigation		7
Neraudia	Yes	Mitigation		12
Solanum Kīpuka ²¹	No	Mitigation	13	18
Waihou II	No	Mitigation		202
Henahena	No	Mitigation		731
Kauila Hala pepe	No	Mitigation		375
Boundary Kīpuka	No	Mitigation		42
Lama Koki'ō	No	Mitigation		382
Anahulu I	No	Mitigation		255
Anahulu II	No	Mitigation		124
Zanthoxylum II	No	Mitigation		815
Stenogyne	No	Mitigation		10
Honohono	No	Mitigation		5
PWW CCA	No	Mitigation		330
Kileo	No	Mitigation		533

²¹ Solanum incompletum 8 individual small units will be incorporated into the Solanum Kīpuka exclosure.

6.3.13 *Stenogyne angustifolia*

1. DOFAW will maintain *in situ* populations through fencing, monitoring, maintenance, and fire protection (*as described in Section 4.3 Avoidance and Minimization*).
2. DOFAW will propagate a complete genetic representation (as is feasible) through seeds and cuttings from the known Pu‘u Anahulu and Pu‘u Wa‘awa‘a populations. These plants will be used to maintain genetic representation of stock and will provide stock for outplanting purposes. This species is currently in propagation at Volcano Rare Plant Facility. Seed and propagule collection will be done following HRPRG (*see Appendix E*).
3. **Mitigation goal:** DOFAW will create and maintain a minimum of **three populations** (in addition to *in situ*) within fenced suitable habitat types to total the take estimate (**325 individuals**). Table 6.15 lists the potentially suitable outplanting sites. Priority will be given to those sites already fenced.
4. **Loss of recruitment mitigation:** DOFAW will create and maintain **one additional population of 50 individuals** following stabilization criteria defined in the recovery plan (USFWS 1993) will be created to mitigate for the potential loss of recruitment for those individuals outside of exclosures. Should values calculated from monitoring data exceed those put forth by the stabilization criteria, those values will be added to this mitigation goal.
5. **Net benefit goal:** In an effort to provide net benefit to Covered Species beyond replacement mitigation, DOFAW will create **one additional population of 50 individuals** following species stabilization guidelines.
6. **Total Mitigation Goal:** In sum, DOFAW will create a minimum of 5 populations with a minimum of 50 mature and reproductive individuals within each population (**for a total of 425 individuals**) that are either a) in separate units, or b) at least 1000 m apart.

Table 6.15 Known *in situ* populations and potential reintroduction sites for *Stenogyne angustifolia*. Bold units contain extant population(s).

Population Unit	Fenced	Management Type	# of Individuals	Unit Size (acre)
Anahulu I	No	Avoidance/minimization	15	255
Stenogyne	No	Avoidance/minimization	43	10
Kīpuka Oweowe	Yes	Mitigation		26
PWW CCA	Yes	Mitigation		330
Po‘ohoho‘o	Yes	Mitigation		29
Hauaina	Yes	Mitigation		49
Zanthoxylum I	Yes	Mitigation		7
Neraudia	Yes	Mitigation		12
Waihou II	No	Mitigation		202
Henahena	No	Mitigation		731
Kauila Hala pepe	No	Mitigation		375
Boundary Kīpuka	No	Mitigation		42
Lama Koki‘o	No	Mitigation		382
Anahulu II	No	Mitigation		124
Zanthoxylum II	No	Mitigation		815
Honohono	No	Mitigation		5
Solanum Kīpuka	No	Mitigation		18
Kileo	No	Mitigation		533

6.3.14 A‘e (*Zanthoxylum dipetalum* var. *tomentosum*)

1. DOFAW will maintain *in situ* individuals through individual fences, monitoring, maintenance, and fire protection (*as described in Section 4.3 Avoidance and Minimization*) to be used as propagule sources for mitigation outplanting.
2. DOFAW will propagate a (as feasible) complete genetic representation through seeds and air layers from the known Pu‘u Wa‘awa‘a individuals. These plants will be used to maintain genetic representation of stock and will provide stock for outplanting purposes. This species is currently in propagation at Volcano Rare Plant Facility. Seed and propagule collection will be done following HRPRG (*see Appendix E*).
3. **Mitigation goal:** The take estimate for this species is **19 individuals**. Because a population made up of such a small number of individuals is likely too small to become self-sustaining over time, we defer to the species stabilization goals outlined in the recovery plan (USFWS 1998a) and defined in Section 5.3.4. DOFAW will create and maintain **three populations of 50 individuals** each within fenced suitable habitat types. Table 6.16 lists the potentially suitable outplanting sites. Priority will be given to those sites already fenced.
4. **Loss of recruitment mitigation:** DOFAW will create and maintain **one additional population of 50 individuals** (following stabilization criteria) which will be created to mitigate for the potential loss of recruitment for those individuals outside of exclosures. Should values calculated from monitoring data exceed those put forth by the stabilization criteria, those values will be added to this mitigation goal.
5. **Net benefit goal:** In an effort to provide net benefit to Covered Species beyond replacement mitigation, DOFAW will create **one additional population of 50 individuals** following species stabilization guidelines.
6. **Total Mitigation Goal:** In sum, DOFAW will create 5 populations with a minimum of 50 mature and reproductive individuals within each population (**for a total of 250 individuals**) that are either a) in separate units, or b) at least 1000 m apart.

Table 6.16 Known *in situ* populations and potential reintroduction sites for A‘e (*Z. dipetalum* var. *tomentosum*).

Population Unit	Fenced	Management Type	# of Individuals	Unit Size (acre)
Waihou I	Yes	Avoidance/minimization	2	211
Waihou II	No	Avoidance/minimization	2	202
PWW CCA	No	Avoidance/minimization and Mitigation	1	330
Po‘ohoho‘o	Yes	Mitigation		29
FBS	Yes	Mitigation		3,744
Henahena	No	Mitigation		731

6.3.15 A'e (*Zanthoxylum hawaiiense*)

1. DOFAW will maintain *in situ* populations through fencing, monitoring, maintenance, and fire protection (*as described in Section 4.3 Avoidance and Minimization*).
2. DOFAW will propagate a complete genetic representation (as is feasible) through seeds and cuttings from the known Pu'u Anahulu populations. These plants will be used to maintain genetic representation of stock and will provide stock for outplanting purposes. This species is currently in propagation at Volcano Rare Plant Facility. Seed and propagule collection will be done following HRPRG (*see Appendix E*).
3. **Mitigation goal:** DOFAW will create and maintain **three additional populations** (in addition to *in situ*) within fenced suitable habitat types to total the take estimate (**218 individuals**). Table 6.17 lists the potentially suitable outplanting sites. Priority will be given to those sites already fenced.
4. **Loss of recruitment mitigation:** DOFAW will create and maintain **one additional population of 50 individuals** following stabilization criteria defined in the recovery plan (USFWS 1996b) will be created to mitigate for the potential loss of recruitment for those individuals outside of exclosures. Should values calculated from monitoring data exceed those put forth by the stabilization criteria, those values will be added to this mitigation goal.
5. **Net benefit goal:** In an effort to provide net benefit to Covered Species beyond replacement mitigation, DOFAW will create **one additional population of 50 individuals** following species stabilization guidelines (USFWS 1996b).
6. **Total Mitigation Goal:** In sum, DOFAW will create a minimum of 5 populations with a minimum of 50 mature and reproductive individuals within each population (**for a total of 318 individuals**) that are either a) in separate units, or b) at least 1000 m apart.

Table 6.17 Known *in situ* populations and potential reintroduction sites for A'e (*Z. hawaiiense*)

Population Unit	Fenced	Management Type	# of Individuals	Unit Size (acre)
Zanthoxylum II	No	Avoidance/minimization	129	815
Anahulu I	No	Avoidance/minimization	9	255
Anahulu II	No	Avoidance/minimization	30	124
FBS	Yes	Mitigation		3,744
Waihou I	Yes	Mitigation		211
Pāpala	Yes	Mitigation		74
Po'ohoho'o	Yes	Mitigation		29
Kīpuka Oweowe	Yes	Mitigation		26
Hauaina	Yes	Mitigation		49
Zanthoxylum I	Yes	Mitigation	7	7
Neraudia	Yes	Mitigation		12
Waihou II	No	Mitigation		202
Henahena	No	Mitigation		731
Kauila Hala pepe	No	Mitigation		375
Boundar Kīpuka	No	Mitigation		42
Lama Koki'o	No	Mitigation		382
Stenogyne	No	Mitigation		10
Honohono	No	Mitigation		5
Solanum Kīpuka	No	Mitigation		18
PWW CCA	No	Mitigation		330
Kileo	No	Mitigation		533

Table 6.18 Summary of Covered Species, avoidance and minimization measures, take estimates, mitigation goals, net benefit goals, net benefit goals, and recruitment loss goals. Net benefit goals follow species stabilization guidelines.

Species	Surveyed	Model Projection	Fenced Individuals	Avoidance & Minimization Exclosures	Take Estimate	Mitigation Goal	Net Benefit Goal	Recruitment Loss Mitigation	Total Mitigation Target
<i>Asplenium peruvianum</i>	64	n/a	45	FBS Unit	19	3 populations of 50 plants each	1 population of 50 plants	1 population of 50 plants	250 plants
<i>Chrysodracon hawaiiensis</i>	299	279	235	Pu'u Loa, Lama Hala pepe, Lama Koki'o, Hala pepe, Kīpuka Oweowe	331	3 populations totaling take estimate	1 population of 25 plants	1 population of 25 plants	381 plants
<i>Colubrina oppositifolia</i>	758	767	692	Pu'u Loa, Lama Hala pepe	805	3 populations totaling take estimate	1 population of 25 plants	1 population of 25 plants	855 plants
<i>Haplostachys haplostachya</i>	80	796	80	Honohono	796	3 populations totaling take estimate	1 population of 50 plants	1 population of 50 plants	896 plants
<i>Hibiscus brackenrdgei</i>	65	59	65	Hibiscus brackenridgei	59	3 populations of 50 plants each	1 population of 50 plants	1 population of 50 plants	250 plants
<i>Kokia drynarioides</i> ²²	4	1	4	Lama Koki'o	1	3 populations of 100 plants each	1 population of 100 plants	1 population of 100 plants	500 plants

²² All known individuals are fenced in individual fences

Species	Surveyed	Model Projection	Fenced Individuals	Avoidance & Minimization Exclosures	Take Estimate	Mitigation Goal	Net Benefit Goal	Recruitment Loss Mitigation	Total Mitigation Target
<i>Mezoneuron kavaense</i>	48	107	11	Uhiuhi 4, Uhiuhi 1, Uhiuhi 2, Pu'u Loa	144	3 populations totaling take estimate	1 population of 50 plants	1 population of 50 plants	244 plants
<i>Neraudia ovata</i>	8	28	8	Neraudia, Anahulu I & II	29	3 populations of 100 plants each	1 population of 100 plants	1 population of 100 plants	500 plants
<i>Nothoestrum breviflorum</i>	156	211	123	Henahena, Waihou I, Kauila Hala pepe, Kīpuka Oweowe, 'Aiea, Lama Koki'o, Po'ohoho'o	265	3 populations totaling take estimate	1 population of 50 plants	1 population of 50 plants	365 plants
<i>Portulaca sclerocarpa</i>	1	n/a	1	Anahulu I	0	3 populations of 50 plants each	1 population of 50 plants	1 population of 50 plants	250 plants
<i>Silene lanceolata</i>	235	1607	30	Anahulu I	1812	3 populations totaling take estimate	1 population of 50 plants	1 population of 50 plants	1912 plants
<i>Solanum incompletum</i>	12	87	14	Solanum	87	3 populations of 100 plants each	1 population of 100 plants	1 population of 100 plants	500 plants
<i>Stenogyne angustifolia</i>	98	285	58	Anahulu I, Stenogyne	325	3 populations totaling take estimate	1 population of 50 plants	1 population of 50 plants	425 plants

Species	Surveyed	Model Projection	Fenced Individuals	Avoidance & Minimization Exlosures	Take Estimate	Mitigation Goal	Net Benefit Goal	Recruitment Loss Mitigation	Total Mitigation Target
<i>Zanthoxylum dipetalum tomentosum</i>	13	11	5 ²³	Waihou I&II, Hala Pepe	19	3 populations of 50 plants each	1 population of 50 plants	1 population of 50 plants	250 plants
<i>Zanthoxylum hawaiiensis</i>	219	176	169	Zanthoxylum II, Anahulu I & II	218	3 populations take estimate	1 population of 50 plants	1 population of 50 plants	318 plants

²³ All known individuals for this species are individually fenced.

6.3.16 Blackburn's Sphinx Moth (*Manduca blackburni*)

Fuelbreak creation and maintenance provides protection from fire for native habitat potentially used by *M. blackburni*. While removal of tree tobacco on fuelbreaks may reduce available non-native host plants, the overall result is a net benefit to the species. Mitigation of covered plant species will include the creation of large conservation units and exclosures for the outplanting of the native host plant 'Aiea, other covered plant species, and potential and known native nectar plant species. The USFWS is currently recommending a 5 to 1 offset ratio for loss of degraded habitat for Blackburn's sphinx moth. For every five acres of degraded habitat lost, one acre of native habitat will be restored. Approximately 38.6 acres of fuel break and 4x4 roads are currently occupied by tree tobacco and are actively cleared (through herbicide and/or manual cutting). By applying the 5 to 1 ratio suggested by the USFWS, we calculate that approximately 7.2 acres of habitat will need to be restored in order to mitigate for this loss of degraded habitat. In the case that tree tobacco colonizes all of the roads and fuel breaks within the Plan Area (totaling approximately 370 km² or 640 acres) we calculate that, using the same ratio as above, 128 acres will be need to be restored for mitigation. FIGURE 6.1 shows the Plan Area with overlays of 'Aiea range data and critical habitat for both 'Aiea and Blackburn's sphinx moth. The mitigation goal for 'Aiea is to have a minimum of three populations totaling 365 individuals. All of the proposed or current exclosures, (totaling approximately 9,000 acres), that will be used for mitigation purposes fall within the range of 'Aiea and far exceed the recommended ratio suggested by the USFWS. Mitigation for losses of Covered Plant species will also provide and enhance native habitat known to be used by Blackburn's sphinx moth.

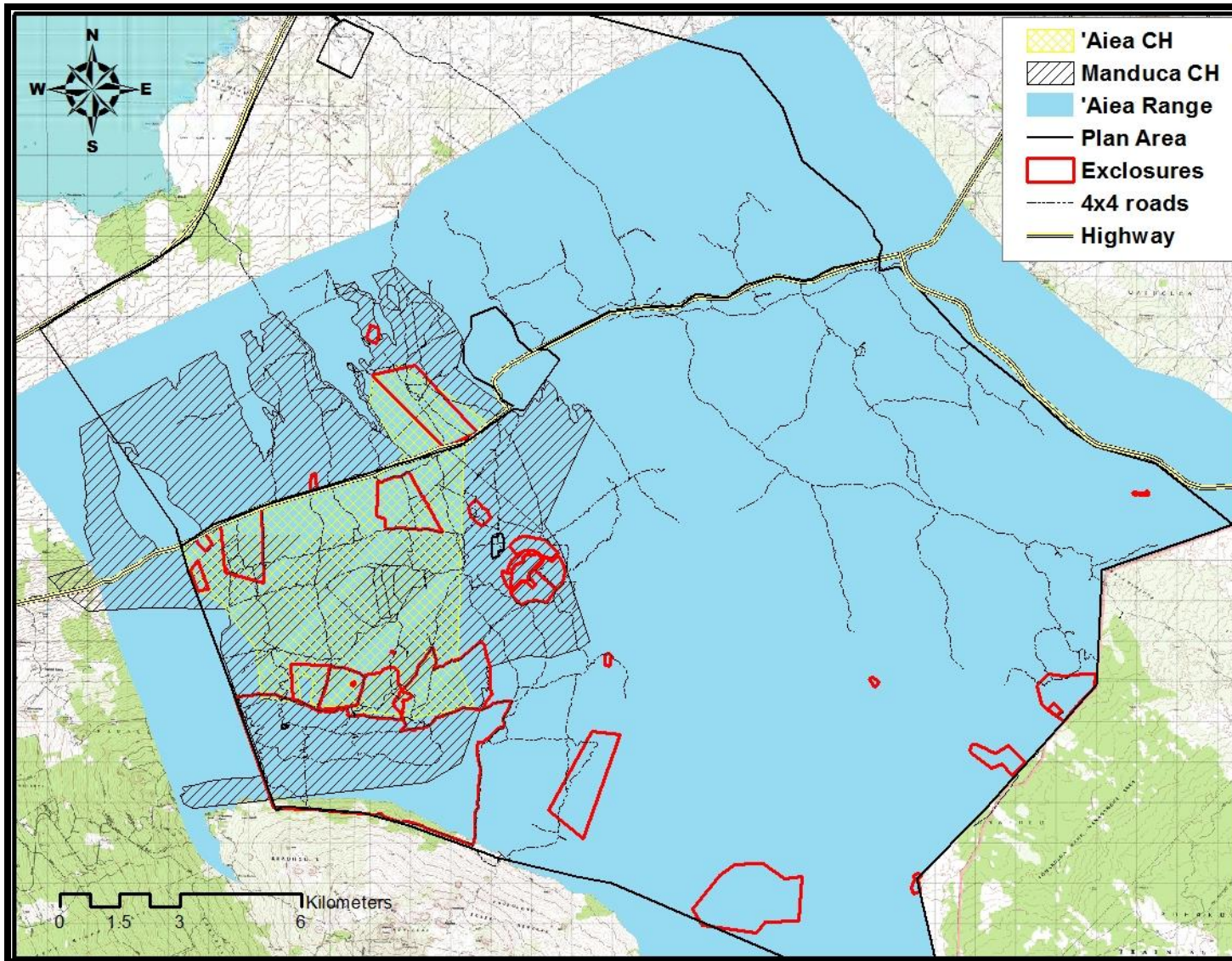


Figure 6.1 Map depicting critical habitat for 'Aiea and *Manduca blackburni*, exclosure locations, and species range for 'Aiea within the Plan Area.

6.4 NET BENEFIT TO COVERED SPECIES

This HCP seeks to offset the potential impact of the proposed game mammal management activities on the listed species (i.e. Covered Species) with measures that protect and provide a net benefit to these species island-wide and statewide. Table 6.19 shows the number of known individuals and populations within the Plan Area, as well as the current island-wide and state-wide plant values (based on USFWS 5 year reviews) for each Covered Species. The combined number of protected (*in situ* and mitigation) plants after the HCP has been implemented compared to the current known and estimated plants in the Plan Area as well as the overall island-wide and state-wide values, show a marked increase in number of protected plants for each of the Covered Species (Figure 6.2). Mitigation targets are set at levels that account for levels of take as well as add additional plant populations to provide a net benefit to each of the covered species (Figure 6.3). The final number of protected individuals of each Covered Species (*in situ* and mitigation) far outweighs what is currently protected by fences through avoidance and minimization actions (Figure 6.4). Table 6.20 shows the percent increase in number of protected species after the HCP has been fully implemented. For all Covered Species there is at least a 100% increase in number of protected plants. While the activities in this HCP lead to the incidental take of Covered Species, project actions will have an overall net benefit to the species covered under this HCP as well as to other non-covered species that occur in the Plan Area.

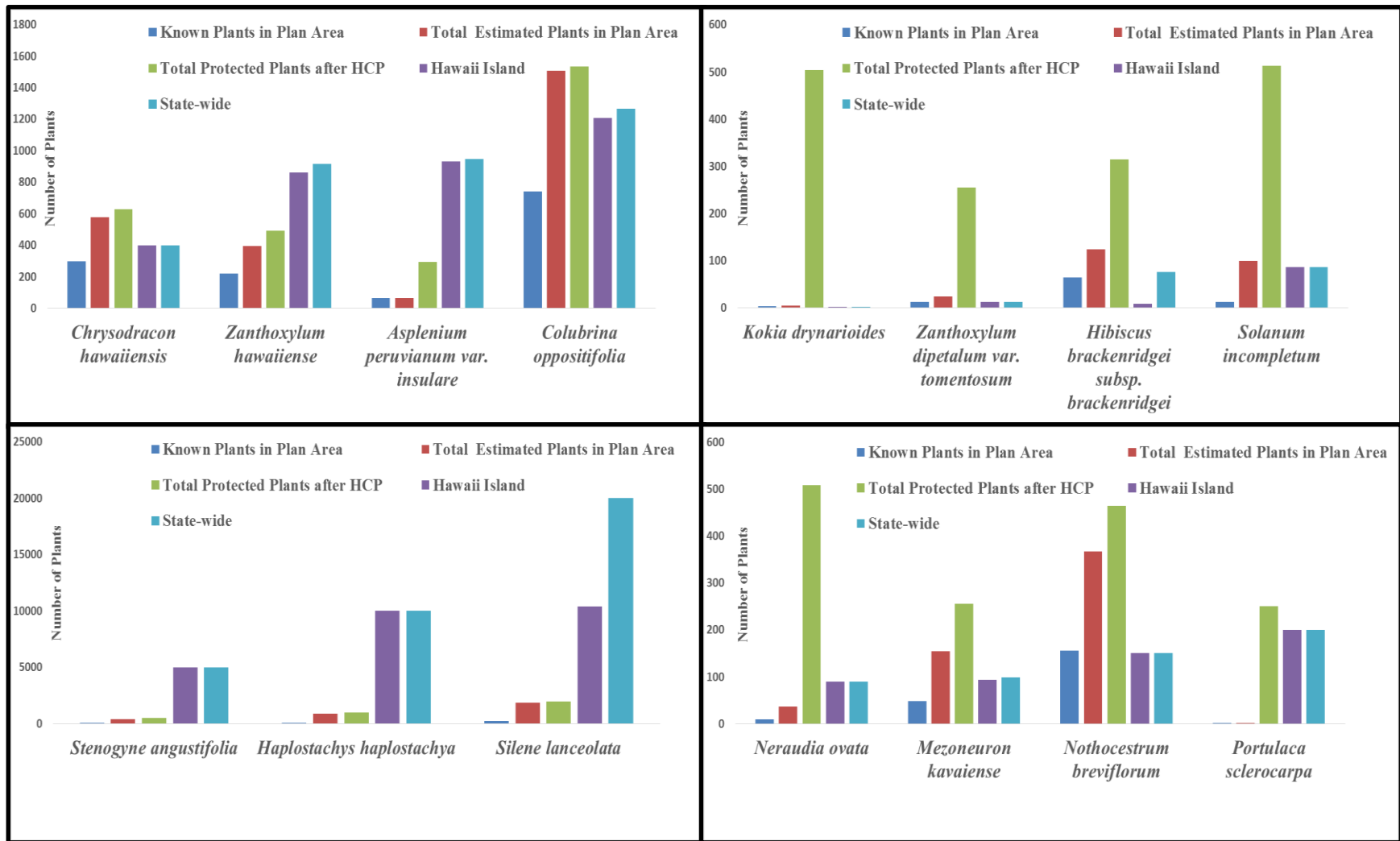


Figure 6.2 A comparison of the number of plants in the Plan Area, with plant numbers from across the island and state. Known plants are those found during surveys, total estimated plants are known plants plus estimated plants from modeling, total protected plants after HCP are both *in situ* and mitigated fenced plants in the Plan Area after implementation. Island and State-wide values come from USFWS 5 year reviews.

Table 6.19 Number of individuals of Covered Species in the Plan Area and across the state. A population is defined as a group of individuals within 1000m of one another. Values for number of individuals across the state come from the most recent USFWS 5 year review and summary evaluation reports for each of the covered Species.

Species	Known Individuals in Plan Area	Populations in Plan Area	State wide	O‘ahu	Hawai‘i	Maui	Kaua‘i	Lāna‘i	Moloka‘i
<i>Asplenium peruvianum</i> var. <i>insulare</i>	64	3	948		931	17			
<i>Chrysodracon hawaiiensis</i>	299	5	400		400				
<i>Colubrina oppositifolia</i>	739	1	1265	54	1209	2			
<i>Haplostachys haplostachya</i>	80	1	10,000		10,000	X	X		
<i>Hibiscus brackenridgei</i> subsp. <i>brackenridgei</i>	65	1	76		9	63		4	
<i>Kokia drynarioides</i>	4	1	2		2				
<i>Mezoneuron kawaiense</i>	48	1	99	4	94	X	1	X	
<i>Neraudia ovata</i>	9	2	90		90				
<i>Nothocestrum breviflorum</i>	156	3	150		150				
<i>Portulaca sclerocarpa</i>	1	1	200		200			X	
<i>Silene lanceolata</i>	235	3	20,000	189	10,394		X		622
<i>Solanum incompletum</i>	13	1	86		86	X	X	X	X
<i>Stenogyne angustifolia</i>	98	3	5000		5,000	X			X
<i>Zanthoxylum dipetalum</i> var. <i>tomentosum</i>	13	2	13		13				
<i>Zanthoxylum hawaiiense</i>	219	2	916		860	51	2	X	3

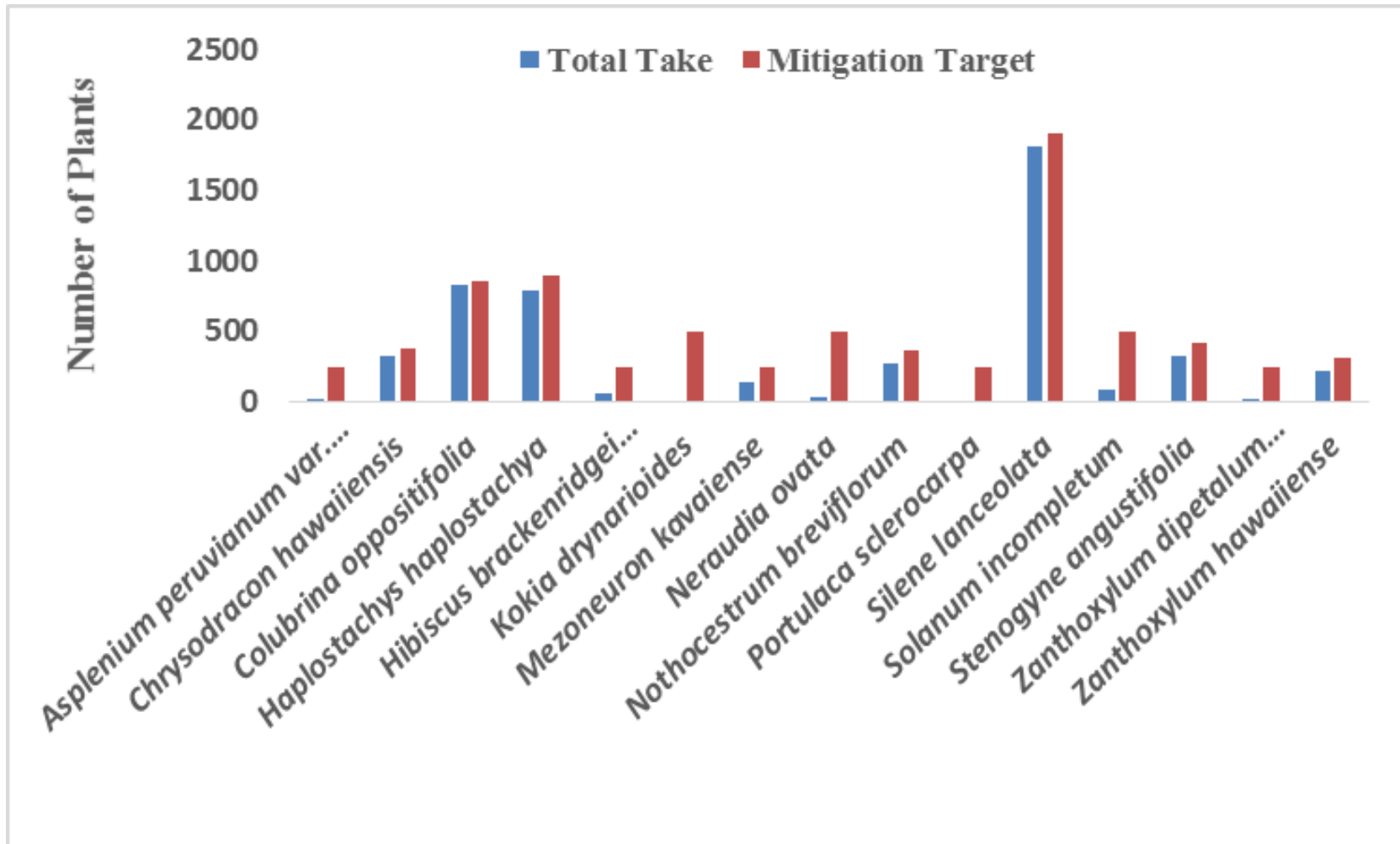


Figure 6.3 Total take (blue bar) values compared to the mitigation target (red bars) for each Covered Species. Total take is calculated based on actual take of known unfenced plants and estimated plants outside of fenced areas.

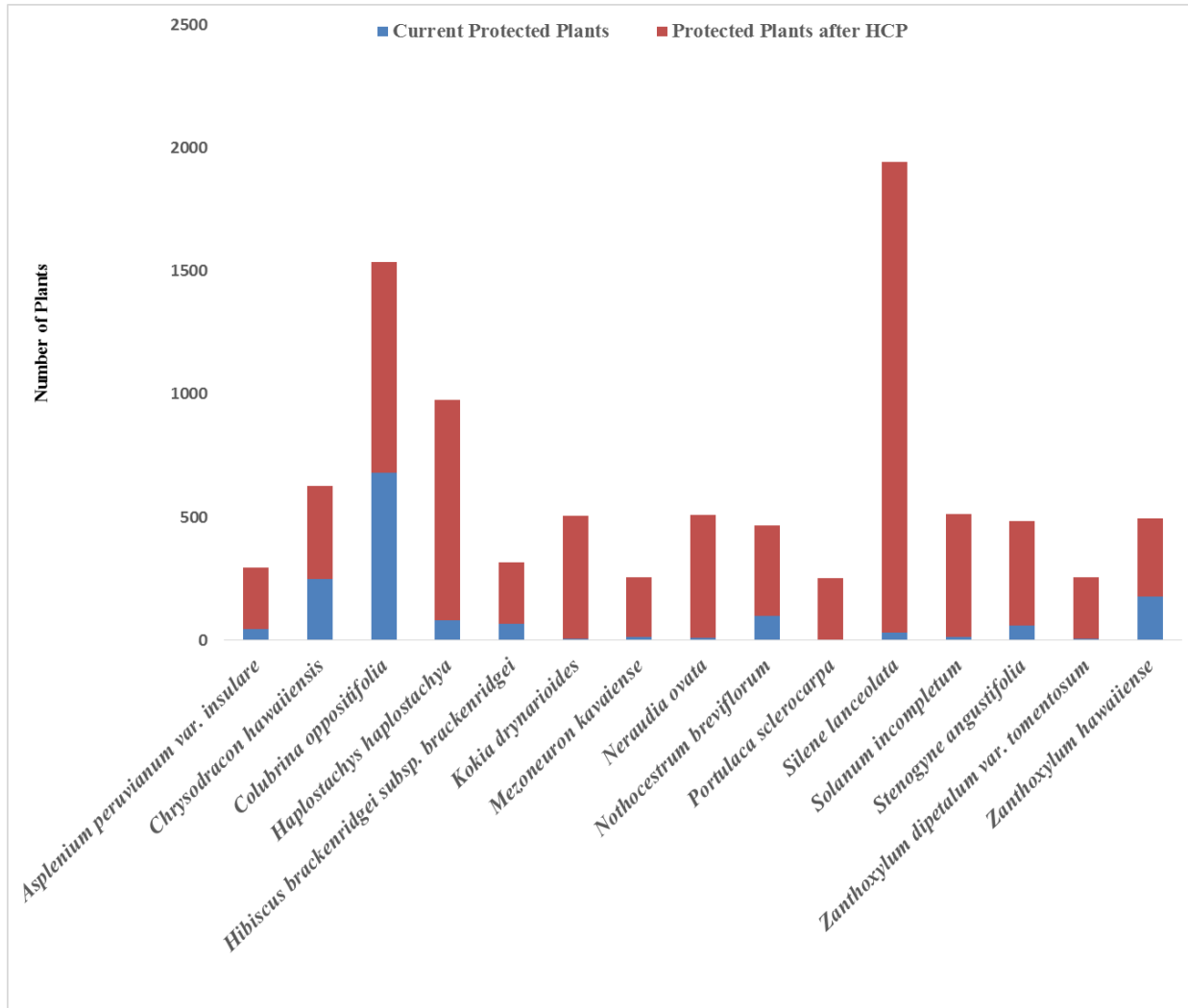


Figure 6.4 Total combined number of protected (fenced) plants after HCP implementation. Blue bars are in situ plants within enclosures and red bars are mitigation (outplanted) plants.

Table 6.20 Percent increase in number of protected plants after HCP implementation.

Species	% Increase
<i>Asplenium peruvianum</i> var. <i>insulare</i>	461
<i>Chrysodracon hawaiiensis</i>	109
<i>Colubrina oppositifolia</i>	102
<i>Haplostachys haplostachya</i>	111
<i>Hibiscus brackenridgei</i> subsp. <i>brackenridgei</i>	254
<i>Kokia drynarioides</i>	10080
<i>Mezoneuron kavaiense</i>	165
<i>Neraudia ovata</i>	1376
<i>Nothoestrum breviflorum</i>	127
<i>Portulacca sclerocarpa</i>	25100
<i>Silene lanceolata</i>	105
<i>Solanum incompletum</i>	513
<i>Stenogyne angustifolia</i>	126
<i>Zanthoxylum dipetalum</i> var. <i>tomentosum</i>	1063
<i>Zanthoxylum hawaiiense</i>	125

6.5 PROPAGULE COLLECTION, STORAGE AND PROPAGATION

Multiple methods for propagule collection and storage are available and are currently being used for *ex situ* conservation of many endangered plant species in Hawai‘i. These methods take two basic forms, either collection of reproductive output (seeds), or the collection of plant vegetative materials. Collection of plant materials can be done as cuttings, air layering, or the collection of whole plants. In general, it has been argued that the collection of seed is preferable to the collection of plant materials (Guerrant et al. 2004). There are two main arguments for this; seed collection is seen as less damaging demographically than taking vegetative matter, and secondly, it is typically much easier and more economical to store seeds than continued maintenance of growing plants in botanical garden or nursery (Guerrant et al. 2004).

All of the plant species covered under this Plan have been or are currently in propagation. As previously discussed, some of the Covered Species are dioecious and individuals are isolated from one another by large distances. For dioecious species in particular, this may lead to long periods of time between seed set. For this reason, collection of plant vegetative material via cuttings or air layering will be used in conjunction with seed collection in order to have genetic representation from as many remaining individuals as feasible. Some individual trees may be senescing from ungulate pressure, competition with invasive species, or old age, therefore seed set may be reduced. The only recourse for the collection of genetic material from these individuals is to take cuttings or air layers. An onsite nursery, potentially located in Hauaina enclosure, will allow for air layers and/or cuttings to be outplanted onsite for future reproductive crosses and monitoring. Hauaina is located in a central area within the Pu‘u Wa‘awa ‘a Ranch, allowing for easy access on a 4x4 road. Water is available on site and can provide for the needs of a nursery. A small greenhouse has been built at the Pu‘u Wa‘awa ‘a baseyard for acclimatizing plants which are propagated elsewhere (e.g. Volcano Rare Plant Facility) to the Plan Area prior to outplanting. A qualified and trained technician will be onsite for nursery needs, as well as seed collection, and may provide additional assistance to field crews when necessary. In the first two years of implementation, a database and associated map will be completed for each Covered Species, that identifies all known plant locations and propagule collection needs. Within five years of implementation, propagules will be collected from each of the known populations within the Plan Area (*See* Table 3.5).

Individual plant enclosures are the smallest type of enclosure being used within the Plan Area. They are generally intended to protect only a single or few individuals of a single species that are very isolated and typically surrounded by invasive species. Because many of these fences are placed around individuals occurring in highly degraded habitat, they are not contributing to the perpetuation of the species in the wild and are not seen as a long-term management option. The fences do, however, provide protection for individuals of species that cannot be reproduced elsewhere, while cuttings, air layers, seeds, or seedlings are collected and propagated for outplanting in other locations. In addition, these small units can be put in place fairly quickly to protect individuals in locations where larger fencing units will be constructed in the future. Because of the small size of these units and limited grazing or watering opportunities, ungulates are rarely observed to enter the fences, therefore avoiding incidents of direct take from

grazing and traffic. However, they offer little opportunity for recruitment of new individuals and population growth if left unattended. In cases where the number, location, or characteristics of a protected plant species is such that management in one of the functional community enclosures is infeasible, we have recommended smaller enclosures to protect the existing plants *in situ* for the purposes of propagule collection.

The following enclosures containing Covered Species will be used as a seed and/or cutting source for outplantings as well as Covered Species found in existing and proposed enclosures (described in Section 6.1.1 and 6.1.2):

- **Koki‘o Unit 1 – <1 acre:** Contains Koki‘o outplants.
- **Uhiuhi 2 – 3 acres:** Contains 2 individuals of Uhiuhi.
- **Uhiuhi 3 – 1 acre:** Contains 1 individual of Uhiuhi.
- **Kokio 2 – <1 acre:** Contains Koki‘o outplants.
- **Pu‘u Wa‘awa‘a 3 – 1 acre:** A variety of lowland dry forest species.
- **Haplostachys Monitoring Enclosure:** 40 x 40 m fenced unit established by the HCP crew, contains about 40-50 plants.
- **Silene Monitoring Enclosure:** 40 x 40 m fenced unit established by the HCP crew, contains about 30 plants.
- **Stenogyne Monitoring Enclosure:** 40 x 40 m fenced unit established by the HCP crew, contains about 20 plants.
- **Zanthoxylum Unit – 12 acres:** Established in 2005 by Pono Pacific in coordination with USFWS.
- **‘Aiea Enclosures:** Eight individual enclosures with the proposed ‘Aiea Conservation unit were established in 2008 and 2009.
- **Neraudia enclosures:** Three small enclosures, one that contains six plants, and two individual tree fences.
- **A‘e enclosures:** All known individuals of *Z. dipetalum* var. *tomentosum* are individually fenced.
- **Pōpolo kū mai enclosures:** All known individuals of *S. incompletum* are individually fenced.

7.0 IMPLEMENTATION

7.1 HCP ADMINISTRATION

A DLNR-DOFAW Implementation Team (DDIT) on the island of Hawai‘i will be established to administer and implement the HCP after BLNR approval and ITL issuance. Other experts may be consulted as needed, including scientists or consultants from other agencies (e.g. USDA Forest Service, USFWS), conservation organizations, or academic institutions. HCP-related issues may also be brought before the ESRC for formal consideration when deemed appropriate by the DDIT and DLNR. Pursuant to HRS Chapter §195D-26, DLNR will provide annual updates to the ESRC on the status of all covered species and the effectiveness of implementation under this HCP. The purpose of the regular meetings will be to evaluate the efficacy of monitoring methods, compare the results of monitoring of the estimated take, evaluate the success of mitigation, and develop recommendations for future monitoring and mitigation. Regular meetings will also provide opportunities to consider the need for adaptive management measures. Additional meetings with the ESRC may be requested by the DLNR to address immediate concerns on the implementation of, or compliance issues related to the HCP. Additional meetings may also be requested by the ESRC at any time to address questions or concerns.

7.2 MONITORING AND REPORTING

Pursuant to Chapter 195D, monitoring and reporting by the DDIT will address both compliance with and effectiveness of monitoring and mitigation measures outlined in the HCP. Compliance monitoring will verify the Applicant’s implementation of the HCP terms and conditions. Annual reports and other deliverables as described below will be provided to the ESRC via DOFAW HCP staff and/or the DDIT to allow the committee to independently verify that required activities and tasks under this HCP are continuing and on schedule. Monitoring will document take relative to authorized levels and the success of the HCP’s mitigation program.

In order to meet the HCP requirements, and to provide an effective and efficient response to changing needs or circumstances, the DDIT will monitor avoidance and minimization measures, and mitigation efforts and results, assess impacts to covered species and compliance with obligations set forth under the HCP, and evaluate potential adaptive management measures. Roles and responsibilities are defined in this section, and the adaptive management strategy is explained as it pertains to regular evaluation of conservation measures and compliance requirements. The below monitoring information is a basic guideline for informational needs and does not constitute a complete monitoring plan. A final, detailed monitoring plan for each Covered Species will be created within three years of the Plans approval and implementation.

7.2.1 Avoidance and Minimization and Mitigation Monitoring

7.2.1.1 Avoidance and Minimization

Each existing and proposed enclosure designated for avoidance and minimization loss, will be surveyed for baseline conditions. DDIT staff will monitor the survival of existing *in situ* populations. If population numbers drop 25% lower than the established baseline, additional management efforts will be initiated.

1. Establish baseline: A full survey of the Covered Species will be done within each of the proposed (upon completion of fencing) and existing exclosures (following HCP approval) with the exception of the FBS unit. Due to the density of vegetation and large size of the FBS unit, regular surveys will be limited to the known Covered Species populations and additional surveying for additional individuals will be done when staff time permits (*for full description of exclosures see Section 4.3.6*). Data to be collected include: location, life stage, vigor, phenological state, and any evidence of ungulate damage. Monitoring data to be collected will follow the recommendations of the HRPRG as closely as possibly (*see Appendix E*).
2. Exclosures will be surveyed annually to follow changes in the population of Covered Species over time. Demographic data by life stage including (growth, survival, reproduction, and recruitment will be analyzed to monitor changes in population abundance over time (declining, stabilizing, or increasing).

7.2.1.2 Mitigation for Covered Plant Species

Each existing and proposed exclosure designated for mitigation and net benefit populations will be monitored to determine the effects of management (fencing, weed control, outplanting) on mitigation populations. If population numbers drop 25% lower than baseline outplanting goals, additional management actions (e.g. investigate causes, conduct additional outplantings, and provide supplemental watering) will be initiated. Additional environmental benefits expected above and beyond the requirements of this HCP will include outplantings of non-covered native plant species, enhanced forest structure for native species, and potential increase in native invertebrate and vertebrate abundance and diversity. Monitoring will include the following:

1. Monitoring survival of outplanted plants:
 - a. A subset of the outplanted individuals will be monitored at 1 month, 3 months, 6, months, 12 months, and then annually.
 - b. Data to be collected include: location, life stage, vigor, phenological state, and any evidence of ungulate damage. Monitoring data to be collected will follow the recommendations of the HRPRG as closely as possibly (*see Appendix E*).
2. At the end of each year, outplanting success will be evaluated and augmentation of outplantings to reach mitigation goals will occur as needed. After year one, a subset of the outplanted population will be monitored to quantify survival rates over time. For herbaceous species, monitoring will begin for signs of reproduction and recruitment at the end of year one. For slow growing woody species, monitoring for reproduction and seedling recruitment will begin at year five, or as soon as marked individuals within the population show signs of reproduction. Detailed monitoring methods will be determined based on field observations and will likely be dependent on species identity and conditions. Possible methods include establishing seedling quadrats around randomly chosen individuals to investigate recruitment.
3. A baseline survey of plant community structure (species composition, abundance, and diversity) and other variables such as invertebrate and vertebrate composition may be

conducted directly after each avoidance and minimization, and mitigation exclosures is built.

7.2.1.3 Invasive Plant Species Monitoring

Increased competition, threat of wildfire, and alteration of micro-site conditions have all been identified as potential negative impacts of alien plant invasions on native plants in Hawai‘i. In order to minimize these risks, invasive species need to be controlled and introductions of new pest species avoided. In order to understand how to best mitigate the threat of invasive species, monitoring will be conducted. The goal for invasive species control for this HCP is to remove 90% of fountain grass and kikuyu grass²⁴ from within 3 meters of an individual (or cluster of) Covered Species and, maintain a 25-50 m buffer of less than 50% invasive grass coverage around an individual (or cluster of) Covered Species.

Methods include:

1. Baseline monitoring: systematic transects with random quadrats will be used (concurrent with Covered Species monitoring) to establish and monitor the composition and abundance of alien plant species in the Plan Area. Monitoring will cover alien plant presence, frequency, cover, and density.
2. Baseline surveys will assist with identifying priority species for control. Initial work will rely on the results and experiences of previous restoration projects and experiments by professional managers and scientists. Pilot trials will also be done to assess the best method(s) of control for a given species.
3. After control is conducted, the presence, frequency, cover, and density of alien plants will be monitored semi-annually or annually to assess the efficacy and efficiency of previous control efforts.
4. Protocols to minimize and respond to introduction of new weed species will be developed within the first three years of HCP implementation.

7.2.1.4 Fence line Monitoring

Fence checks will be done quarterly to ensure fence integrity and regular inspection of ungulate ingress occurs. In addition, fences will be checked more frequently if there are sufficient reasons to believe a fence may have been damaged (e.g. after a storm). If fences are found to be breached, fence will be repaired and any ungulates that have entered the fence unit will be removed.

²⁴ Fountain (*Pennisetum setaceum*) and kikuyu (*Pennisetum clandestinum*) grass have been identified as the most damaging invasive plant species in the Plan Area. Additional weed species will be controlled on a case by case basis. Some alien species, such as kikuyu grass can hinder the encroachment of more aggressive weed species allowing for better outplanting conditions and can be left in place until outplants are near ready to be planted.

7.2.1.5 Blackburn's Sphinx Moth and Tree Tobacco Monitoring

Annual monitoring of 'Aiea outplants for presence of Blackburn's sphinx moth will begin 5 years post-outplanting. A minimum of three outplanting sites will be chosen to monitor for presence of larvae during the peak larval season (Dec-Feb).

Monitoring of tree tobacco will include biennial surveys of roadsides and fuel-breaks in the Plan Area. Roads will be surveyed annually either by driving, helicopter flight, or UAV (unmanned aerial vehicle). Dependent upon the methodology employed, a map and distribution and abundance estimate will be calculated after each survey. This data will be used to calculating area cleared in the Plan Area annually.

7.2.2 Monitoring Impact on Each Covered Species

The biological conditions associated with the HCP shall be monitored to determine if the species needs are being met. Monitoring impact to the species should include collection of quantitative and qualitative data needed to ensure that take is not likely to cause the loss of genetic representation of the affected population, that net benefit to the species and environment is being provided, and that mitigation activities are contributing to the recovery of the species. The effectiveness of monitoring will help the DLNR and ESRC to determine if the conservation strategy is functioning as intended and if the anticipated benefits to the species are being realized. Monitoring of mitigation efforts for Covered Species is intended to inform the DDIT, ESRC and DLNR whether these efforts are adequately compensating for take. If monitoring reveals that a particular mitigation effort is not achieving the necessary level of success, the DDIT will consult with ESRC and DLNR to develop and implement a revised mitigation strategy to meet mitigation requirements.

7.2.3 Compliance Monitoring

Compliance monitoring is intended to document implementation of mitigation activities in accordance with the HCP schedule and related agreements. Compliance monitoring is especially critical to ensure timely identification of site-specific conditions or problems that should be addressed through adaptive management or other measures. Monitoring should include collection of the required quantitative and qualitative data needed to assess the effectiveness of mitigation measures. Compliance monitoring may be conducted in concert with monitoring impact to the species.

Compliance monitoring will necessarily be site and management action specific, and depend on the goals and measures of success for that activity under the HCP. Specific protocols for compliance monitoring should be approved by the agencies and ESRC prior to, or as part of, approval of specific mitigation actions.

Generally, compliance monitoring will be conducted by the party or parties responsible for carrying out the mitigation activities, in accordance with the schedule set forth in the approved compliance monitoring protocol. DOFAW HCP administrative staff or their designees will also provide periodic on-site monitoring to ensure HCP-related activities are being performed in accordance with the HCP and related agreement(s) on at least an annual basis, but usually not more than semi-annually in order to minimize costs.

7.2.4 Annual Reporting

Annual reporting is required by state law (HRS §195-D). Additional reporting may be advantageous to address emergencies, special circumstances, or changes in condition that should be addressed more quickly than response to an annual report would deliver (e.g., a die-off event, drastic changes in funding or costs, or drastic changes in the level of impact or mitigation effectiveness).

Annual reports will be submitted by the DDIT by August 1 of each year, covering the 12-month period July 1 through June 30. The DDIT will confer with DOFAW HCP staff following the submittal of the annual report to review the results and discuss future HCP implementation issues. Annual reports will also be made available to the ESRC.

Annual reports should include:

1. A summary of HCP requirements (including requirements in the HCP, incidental take license, and other agreements or documents incorporated by the HCP and/or incidental take license), measures to ensure compliance with these requirements and schedule, and recommendations for actions and schedule needed to address any non-compliance issues that arise.
2. Adaptive management approaches and recommended changes for improvement under adaptive management, and the basis for such changes.

Annual review does not preclude other review or discussion. Discussion, review, and implementation of measures to address immediate, time-sensitive concerns, or as needed for the welfare of the species, or as required by the HCP, should be accomplished in a timely manner, as appropriate and feasible, and should not be delayed for completion of the annual review.

7.3 ROLES AND RESPONSIBILITIES

Annual reports will include a summary of avoidance and minimization measures and their schedule, monitoring methods and results, collaborative efforts with HCP staff, and identification of problems and solutions. Reports will also include if applicable: requests for technical advice and recommendations for changes through adaptive management. The report should identify any planned changes or additions to facilities or actions which have the potential to increase or decrease impact to protected species, proposed changes to avoidance and minimization measures, and/or monitoring in the following year. All raw data in electronic and/or hard copy form will be attached to the annual report.

Failure to submit adequate reports as required by the ITL is a violation of the permit and may lead to permit suspension or revocation. If a report required by the permit is not submitted or is inadequate, the DDIT will be notified in writing and offered at least 30 days to demonstrate compliance.

The annual report will include the following information:

1. A summary of all actions funded, planned, completed or not completed in the time period of the report.
2. Circumstances that triggered adaptive management and how the adaptive management was implemented.
3. Description of problems that occurred and how they were handled.
4. Description of cost expenditures and other information related to funding assurances.
5. An annual work plan including an implementation schedule and entities responsible for implementation.
6. Other pertinent information such as actions taken by any regulatory agencies related to implementation of the HCP.

The results of monitoring reports will be evaluated by the DLNR HCP administrative staff to determine the level of take that is occurring. Depending on these results, mitigation efforts may be increased or decreased accordingly. Any changes in mitigation will be done in concurrence with the ESRC and the DLNR. Regardless of the changes to mitigation however, the avoidance and minimization efforts will remain for the duration of the HCP.

7.4 ADAPTIVE MANAGEMENT

The concept of adaptive management was first applied to natural resource management by (Holling 1978), and is a concept summarized as “learning by doing,” where feedback from research would be explicitly incorporated into subsequent decisions regarding resource management. In its simplest form, adaptive management is an approach to moving forward in the face of inevitable uncertainties, and emphasizes the need to treat policies and decisions explicitly as hypotheses and opportunities for learning rather than as final solutions.

Under HRS Chapter §195D-21(b)(H) adaptive management in an HCP should specify the actions to be taken periodically if the plan is not achieving its goals. An adaptive management strategy would include a range of possible adjustments and the circumstances under which they would be triggered. Rather than delay the process while sufficient information is gathered to predict the

outcome accurately, the DLNR administrative staff and DDIT should jointly develop the adaptive management strategy. Thus, all parties will be assured of an agreeable outcome. However, adaptive management should not replace crafting and implementing appropriate conservation measures up-front.

In the case of this HCP, some uncertainty exists from the estimated rates of take to the future success of the proposed mitigation measures. Adaptive management will ensure that the results of biological monitoring are integrated into future management decisions and actions and will enable annual evaluation of HCP requirements, management plans, goals and objectives. Adaptive management must be employed to achieve this HCP's biological goals and objectives and will rely heavily on feedback from the monitoring and reporting program.

7.4.1 Adaptive Management to Address Habitat Improvement

Management plans and guidelines prepared for this HCP will:

1. Identify the uncertainty and the questions to be addressed to resolve the uncertainty.
2. Develop alternative strategies and determine which experimental strategies to implement.
3. Integrate a monitoring program able to detect the necessary information for strategy evaluation.
4. Incorporate feedback loops linking implementation and monitoring to appropriate changes in management.

7.4.2 Adaptive Management for Covered Plant Species

As more information is learned about the plant propagation rates, outplanting success, and pest management within the Plan Area, avoidance, minimization, and mitigation measures will be adjusted accordingly. For example, we may find through monitoring and research that certain species of plants do better in certain exclosures or microsites and will need to adjust outplanting protocols or sites accordingly. Likewise, information gained on plant pest control methods may allow us to improve mitigation measures, thereby enhancing survival. New information and methods will be considered whenever brought to the attention of the DDIT or DLNR and will be considered in recommendations for changes through adaptive management. Adaptive management changes may address increased efficiency or effectiveness in assessment of impacts and net benefit, avoidance and minimization, as well as mitigation. Adaptive management recommendations should be reviewed promptly by the DLNR, and approved measures implemented in a timely manner.

7.4.3 Adaptive Management for Blackburn's Sphinx Moth

As more information is learned about the density, distribution, and biology of Blackburn's sphinx moth within the Plan Area, avoidance, minimization, and mitigation measures will be adjusted accordingly. For example, we may find through surveys that Blackburn's sphinx moth occur only at certain elevations, within certain plant communities, or at specific times of year. We can then utilize this information to improve removal methods for invasive tree tobacco, while encouraging native habitat. Likewise, information gained on predator or parasitoid interaction with Blackburn's sphinx moth may allow us to improve mitigation measures, thereby enhancing survival. New information and methods will be considered whenever brought to the attention of the DDIT or DLNR and will be considered in recommendations for changes through

adaptive management. Adaptive management changes may address increased efficiency or effectiveness in assessment of impacts and net benefit, avoidance and minimization, as well as mitigation. Adaptive management recommendations should be reviewed promptly by the DLNR, and approved measures implemented in a timely manner.

7.4.4 Other Adaptive Management Methods

Adaptive management also may be used to update management strategies to 1) redefine conservation measures or 2) incorporate conservation measures recommended in future recovery plans for the Covered Species. If new techniques become available for more effective implementation of the conservation measures, then revisions in the HCP will be made as soon as practicable.

7.5 FUNDING

Sufficient funding will be made available to ensure that the proposed measures and actions in the HCP are undertaken in accordance with the schedule. An estimate of the costs of funding the proposed mitigation and avoidance and minimization plan is presented in Appendix H.

Funding for the implementation of the HCP will be provided by the DLNR as an annual operating expense paid *pari passu* with other operating expenditures (operation and maintenance costs, insurance, payroll, audit costs, and agency fee costs). The DLNR is committed to request funding in every biennial budget to support the proposed monitoring and mitigation measures for the life of the ITL. Any short-fall in funding will require consultation on whether the reduced funding will impact the success of the required measures outlined in the HCP, if adaptive management measures are appropriate, and if compliance with permit obligations are no longer upheld. The DLNR will work under the constraints of its program to ensure adequate funding for implementation of the HCP is provided.

7.6 CHANGED CIRCUMSTANCES PROVIDED FOR IN THE HCP

Circumstances may change during the life of an HCP, some of which can be anticipated and planned for. Possible changed circumstances that may be anticipated and planned for include: 1) climate change; 2) disease outbreaks in any of the Covered Species; 3) deleterious changes in relative abundance or composition of non-native plant species; 4) ungulate ingress into the mitigation or avoidance and minimization units for Covered Species; 5) hurricanes or other major storms or disturbances that may affect the Plan Area and/or mitigation sites; 6) the de-listing of any species covered in the HCP; and 7) the listing of one or more species that already occur on-site, not currently covered in the HCP.

The procedures to provide for these scenarios are described below:

1) Global Climate Change Significantly and Negatively Alters Status of the Covered Species

Global climate change within the life of the Plan (25 years) has potential to alter the current distribution of vegetation communities utilized by Covered Species through region-wide changes in weather patterns, sea level, average temperature, and levels of precipitation (IPPC 2007). In some instances, climate change may cause populations of Covered Species to decline. Covered Plant Species are especially likely to be affected by changes in precipitation. The Blackburn's sphinx moth is unlikely to be affected by any changes in climate over the life of the Plan due to

its ability to utilize non-native habitats which are unlikely to decrease in availability during that time frame.

Studies have shown a trend of increasing frequency and intensity of hurricanes over the last 30 years, possibly linked to global climate (Webster et al. 2005, CCSP 2009), which may increase the risk of damage to the Plan Area. This is discussed in more detail below. Sea level is predicted to rise approximately one meter in Hawai‘i by the end of the 21st Century (Fletcher 2009). Given this prediction, any rise in sea level experienced during the life of the Plan would likely be less than one meter. As the Plan Area ranges in elevation from approximately 20 m to 1700 m, these sites are unlikely to be impacted by sea level rise in the next 25 years (Plan life).

It has been predicted that wet season (winter) precipitation will decrease by 5% to 10%, while dry season (summer) precipitation will increase by about 5% (Giambelluca et al. 2009, Timm and Diaz 2009). This may result in altered hydrology at the Plan Area, with lower elevation units receiving reduced precipitation. To mitigate for this, fencing units at higher elevations may be used for outplanting a given Covered Species despite being outside of its current range.

Vegetation at mitigation sites may also change due to decreased precipitation or increased temperatures and wildfire occurrence. Although changes are expected to be small over the lifetime of the Plan, they are much less predictable in the long term. Should significant changes in vegetation occur, and it is demonstrated that there is a negative impact to Covered Species, other outplanting sites may be considered for continued mitigation. These sites will be chosen in consultation with DLNR administrative staff. In all cases, mitigation efforts will remain commensurate with requested take with a net benefit provided to each Covered Species as required by State law. Changes in the implementation of mitigation measures for any of the Covered Species due to climate change will be incorporated into management actions supporting this HCP so as to successfully meet the objectives outlined in this document.

2) Deleterious change in relative abundance of non-native plant species, ungulates, parasites, disease outbreak, or predators occurring at the mitigation sites for Covered Species

Should the proportion or coverage of non-native plant species, parasites, or predators increase at any mitigation site to a point where it is believed that this change is causing significant increases in mortality for the Covered Species and thereby resulting in a measurable decline of the species at the site, the DDIT will consult with DLNR to determine if measures to prevent the further spread of non-native plants, parasites, or predators are available, practical and necessary. If no such measures are available, mitigation measures for the affected Covered Species may be implemented at another site as determined by DLNR. These actions will be implemented if mitigation actions have not yet been fully achieved or if unmitigated take remains.

3) Ungulate ingress into the mitigation or avoidance and minimization units for Covered Species

Monitoring of exclosures for ungulate ingress will be conducted on a quarterly basis. Should ungulate ingress occur, animals will be removed and Covered Species populations will be evaluated for impacts. If it is deemed there has been a negative impact to mitigation or *in situ* Covered Species populations, mitigation efforts will be modified accordingly to ensure appropriate mitigation targets are achieved.

4) Natural Disasters Such as Hurricanes and Severe Storms

Natural disasters, including hurricanes and storms, have the potential to significantly affect the status of one or more of the Covered Species. Such disasters could also greatly hinder or disrupt mitigation efforts. Mitigation actions may be modified in order to meet outlined mitigation goals in the event of a natural disaster if mitigation actions have not been fully achieved or if unmitigated take remains.

It is not known how the Blackburn's sphinx moth or its habitat will respond to storms or hurricanes. However, we will implement changes in monitoring, reporting, or mitigation deemed appropriate by DLNR if necessary. The budget incorporates funding to enable mitigation objectives to be met in the face of anticipated natural disasters if mitigation actions have not been fully achieved or if unmitigated take remains.

5) De-listing of Covered Species

Should any of the species covered in the HCP be de-listed during the tenure of the permit, it is expected that the mitigation efforts provided by this HCP would have contributed in some part to the de-listing of the species. Therefore, mitigation actions for that species will continue to be performed in accordance with the HCP, unless and until the DLNR and ESRC agree that such actions may be discontinued.

6) Listing of One or More Species that Already Occur On-site

In the event that one or more species that occur on-site are listed pursuant to the ESA, DLNR will evaluate the degree to which the species is/are at risk of being incidentally taken by Plan operations. If take of the species appears possible, DLNR will then assess whether the mitigation measures already being implemented provide conservation benefits to the newly listed species and if any additional measures are needed to provide a net conservation benefit to the species. DLNR would then seek coverage for the newly listed species under an amendment to the HCP.

7.7 UNFORESEEN CIRCUMSTANCES AND “NO SURPRISES” POLICY

Unforeseen circumstances are “changes in circumstance surrounding an HCP that were not or could not be anticipated by HCP participants, DLNR, and ESRC, which result in a substantial and adverse change in the status of a Covered Species” (USFWS and NMFS 1996). Under the “No Surprises” policy, with a properly implemented HCP (HRS §195D-23), the Applicant will not be required to commit additional land, water, money or financial compensation, or be subject to additional restrictions on land, water or other natural resources to respond to such unforeseen circumstances beyond what has been already agreed upon in the HCP, without the consent of the Applicant. For the purposes of this HCP, changes in circumstances not provided for in Section 7.6 that substantially alter the status of the Covered Species are considered unforeseen circumstances.

The “No Surprises” policy assurances only apply to species “adequately covered” in the HCP. Species considered to be “adequately covered” are those covered by the HCP that satisfy the permit issuance criteria under HRS §195D-21. The species considered adequately covered in this HCP and therefore covered by the No Surprises policy assurances include the *Asplenium peruvianum* var *insulare*, Hala pepe (*Chrysodracon hawaiiensis*), Kauila (*Colubrina oppositifolia*), Honohono (*Haplostachys haplostachya*), Ma‘o hau hele (*Hibiscus brackenridgei* ssp. *brackenridgei*), Koki‘o (*Kokia drynarioides*), Uhiuhi (*Mezoneuron kavaiense*), *Neraudia ovata*, ‘Aiea (*Nothocestrum breviflorum*), Po‘e (*Portulaca sclerocarpa*), Hawaiian Catchfly (*Silene lanceolata*), Pōpolo kū mai (*Solanum incompletum*), *Stenogyne angustifolia*, A‘e (*Zanthoxylum dipetalum* var. *tomentosum*), A‘e (*Zanthoxylum hawaiiense*), and the Blackburn’s sphinx moth (*Manduca blackburni*).

In the event that unforeseen circumstances occur during the term of the ITL and the DLNR concludes that any of the Covered Species are being harmed as a result, the DLNR may require additional measures from the DDIT where the HCP is being properly implemented, only if such measures are limited to modifications of the conservation program for the affected species and maintain the original terms of the HCP to the maximum extent possible. Additional conservation and mitigation measures will not involve the commitment of additional land, water or financial compensation or additional restrictions on the use of land, water, or other natural resources otherwise available for development or use under the original terms of the HCP without the consent of the DDIT.

7.8 NOTICE OF UNFORESEEN CIRCUMSTANCES

DLNR HCP administrative staff will have the burden of demonstrating that unforeseen circumstances exist, using best available scientific and commercial data. The DLNR will notify the DDIT in writing should the DLNR believe that any unforeseen circumstance has arisen.

7.9 PERMIT DURATION

The HCP for North Kona Game Management is written in anticipation of the issuance of an ITL to cover the entire Plan duration of 25 years.

7.10 AMENDMENT PROCEDURE

Different procedures are present that allow for amendment to the ITL. However, the cumulative effect of any amendments must not jeopardize any listed species. ESRC and DLNR must be consulted on all proposed amendments and the amendment procedures are listed below.

7.10.1 Minor Amendments

Minor amendments include routine administrative revisions and changes to surveying or monitoring protocols that do not decrease the level of mitigation or increase take greater than 10%. A request for a minor amendment to the HCP may be made with written notice to the ESRC and DLNR HCP Administrative staff. The amendment will be implemented upon receiving concurrence from the DLNR.

7.10.2 Major Amendments

Major amendments are required when the Applicant wishes to significantly modify the Plan, activity, or conservation program already in place. Formal amendments are also necessary to add species to the HCP that were not originally covered or to implement adjustments required due to unforeseen circumstances. An amendment to the ITL requires prior written notification to the DLNR Administrative staff requesting an amendment to the HCP that addresses the new changed circumstance(s) and the adaptive measures that are proposed. Such applications typically require a revised HCP, a revised implementing agreement, and may require environmental review documents in accordance with Hawaii Environmental Policy Act (HEPA) as well as the approval of the BLNR. All major amendments will require consultation with the ESRC and the specific documents required may vary based on the nature of the amendment.

7.11 RENEWAL AND EXTENSION

This HCP proposed by the Applicant may be renewed or extended, and amended if necessary, beyond its initial 25-year term with the approval of the ESRC and BLNR. A written request will be submitted that will certify that the original information provided is still current and conditions are unchanged, or a description will be provided with relevant changes to the implementation of the HCP that will take place. The request will also provide species-specific information concerning the level of take that has occurred during the HCP's implementation. Such a request shall be made within at least 180 days of the conclusion of the 25-year term, and the HCP shall remain valid and in full force while the renewal or extension is being processed. The permit may not be renewed for levels of take beyond those authorized by the original permit.

8.0 APPENDIX A: MAMMAL TRACKING STUDY

8.1 INTRODUCTION

A study was initiated to understand the home range sizes of game mammals in the Plan Area in 2004. The primary objectives were to capture and monitor the movements of wild sheep, goats, and pigs and to establish the “Area of Potential Impact” of game mammals produced on or using the Plan Area (*See section 1.3.1 for a full description*).

8.2 METHODS

8.2.1 Capture and tagging techniques

Fifteen feral sheep (8 rams and 7 ewes) were captured and fitted with radio collars (Wildlife Materials model HLPM-31100 Magnum, Carbondale, IL, 2-year expected battery life) during September and October 2003. Five feral goats (4 billies and 1 nanny) were also captured and fitted with radio collars during this period.

A Hughes 500 helicopter was used to assist with capture of all sheep and goats. Initially a lasso attached to a pole was utilized to noose and capture the desired animal. One person held the rope in the helicopter while another person, the ‘mugger,’ jumped off the ship and controlled the animal. This method was somewhat successful and allowed for the capture of a specific animal. In practice, it proved somewhat difficult to get the helicopter close enough for the capture, and sometimes required repeated passes and prolonged chasing of the animal. No animals were stressed enough to preclude them from the study.

After the initial two days with the noose method, we switched to a net gun consisting of a modified 308 rifle firing a quad-weighted 12 x 12 ft parachute cord net. After the desired animal was netted, the mugger jumped out and restrained the animal until the helicopter could land and an additional person would assist in the tagging procedure. The net gun was the more efficient method, and allowed particular animals to be captured from within a herd.

Five feral pigs were captured in box traps at various locations in PWWFR during September and October 2004. The traps were baited for several weeks prior to being set. Traps were baited with expired produce and bakery products donated by a local grocery store in Kamuela. Macadamia nuts were also used in some instances. Following the attachment of radio collars, each animal was given a brief physical examination. Approximate age based on dental eruption patterns and horn length or physical size and sex were recorded.

Selection of animals

We intentionally captured only one sheep or goat from a particular herd in order to maximize information collected on the behavior, composition and movements of different herds. We targeted animals of different age classes and sexes. We attempted to select animals from all portions of the study area. This was fairly easy to accomplish with sheep, except in the makai areas below Māmalahoa highway, where sheep densities have been low in recent history. Goats tended to occupy more discrete areas within the study site, primarily on rough ‘a‘ā flows and near areas with numerous caves. The capture locations for goats reflect this distribution pattern. We also found that pigs were distributed in a clumped pattern, primarily in the wetter portions of the study area. For this reason, pigs were trapped only at three locations within the PWWFR. To determine how frequently and to what extent ungulates produced on or using portions of the Plan

Area affected resources on adjacent lands, we selected sheep and goats at PWWFR that were near borders with adjacent land owners.

Tracking protocol

For all ungulates that were radio collared, the goal was to track and obtain a visual observation once every two weeks. We used ground-based tracking almost exclusively in order to determine behavior, herd size and composition. Our specific approach was to begin tracking and get as close as possible in a truck or ATV. Then we followed the signal on foot and exercised caution to not spook the animal as we closed in on its location. A visual confirmation was nearly always obtained, except in several instances with pigs. After recording field notes we allowed the animal(s) to move off undisturbed, then walked to the location where the animal was seen and recorded a GPS location. This allowed for virtually no locational error in our data set. Occasionally (on three instances) several animals were tracked from a helicopter due to their remote location or if we had exceptional difficulty locating them from the ground.

Garmin 12XL handheld GPS units were used and the location was recorded in UTM WGS 84 format. The observations were compiled in a Microsoft Excel database and later imported into ArcView 3.2 and plotted as home ranges (95% and 50% kernels) and movement patterns. Routine radio tracking ended on April 12, 2005, at which time we had collected sufficient data to fulfill the objectives. To calculate home range size, we used the Animal Movements extension in ArcView 3.2. Home ranges were calculated as 95% adaptive kernels, and core areas were reported as 50% adaptive kernels (ad hoc smoothing parameter for both). We report average home range sizes within the present study.

8.3 RESULTS

8.3.1 Home Range

Ungulate descriptions, tracking data, and the fate of study animals followed during the tracking study are summarized in Table 8.1. Data gathered from game mammal home ranges was used to determine the geographic scope of the area of impact, hereafter “Area of Potential Impact (149,228 acres)”. The calculated home ranges for mammals in the Plan Area are 9.35 km² for female sheep, 12 km² for male sheep, and 16.3 km² for goats. The largest of the three home ranges (16.3 km² for goats, or 2.25 km diameter) was used to calculate the area of potential impact. Figure 8.1 summarizes the current home range results for sheep, pigs, and goats in the region.

Table 8.1 Female sheep tracking data results indicating age, date tagged, number of times the animal was located, and the 95% Kernel home range size (km²).

Age	Date Tagged	Locations	95% Kernel HR size (km²)
1	09/11/04	13	16.17
1	10/09/04	14	7.36
2	09/03/04	26	13.57
2	09/03/04	10	8.69
2	09/03/04	9	6.59
2+	09/02/04	11	11.65
3+	09/11/04	13	1.41
Average HR Size			9.35

Table 8.2 Male sheep tracking data results indicating age, date tagged, number of times the animal was located and the 95% Kernel Home range size (km²).

Age	Date Tagged	Locations	95% Kernel HR size (km²)
1	09/02/04	6	9.18
2	10/09/04	11	3.79
2+	10/09/04	10	10.25
3+	09/11/04	11	21.28
3+	09/11/04	8	18.67
4+	09/02/04	13	8.92
Average HR Size			12.02

Table 8.3 Goat tracking data results indicating sex, age, date tagged, number of times the animal was located and the 95% Kernel Home range size (km²).

Sex	Age	Date Tagged	Locations	95% Kernel HR size (km²)
Female	2	10/09/04	8	35.74
Male	.75	10/09/04	8	19.21
Male	2	10/09/04	11	7.57
Male	2	10/09/04	9	13.34
Male	3+	09/11/04	12	5.65
Average HR Size				16.30

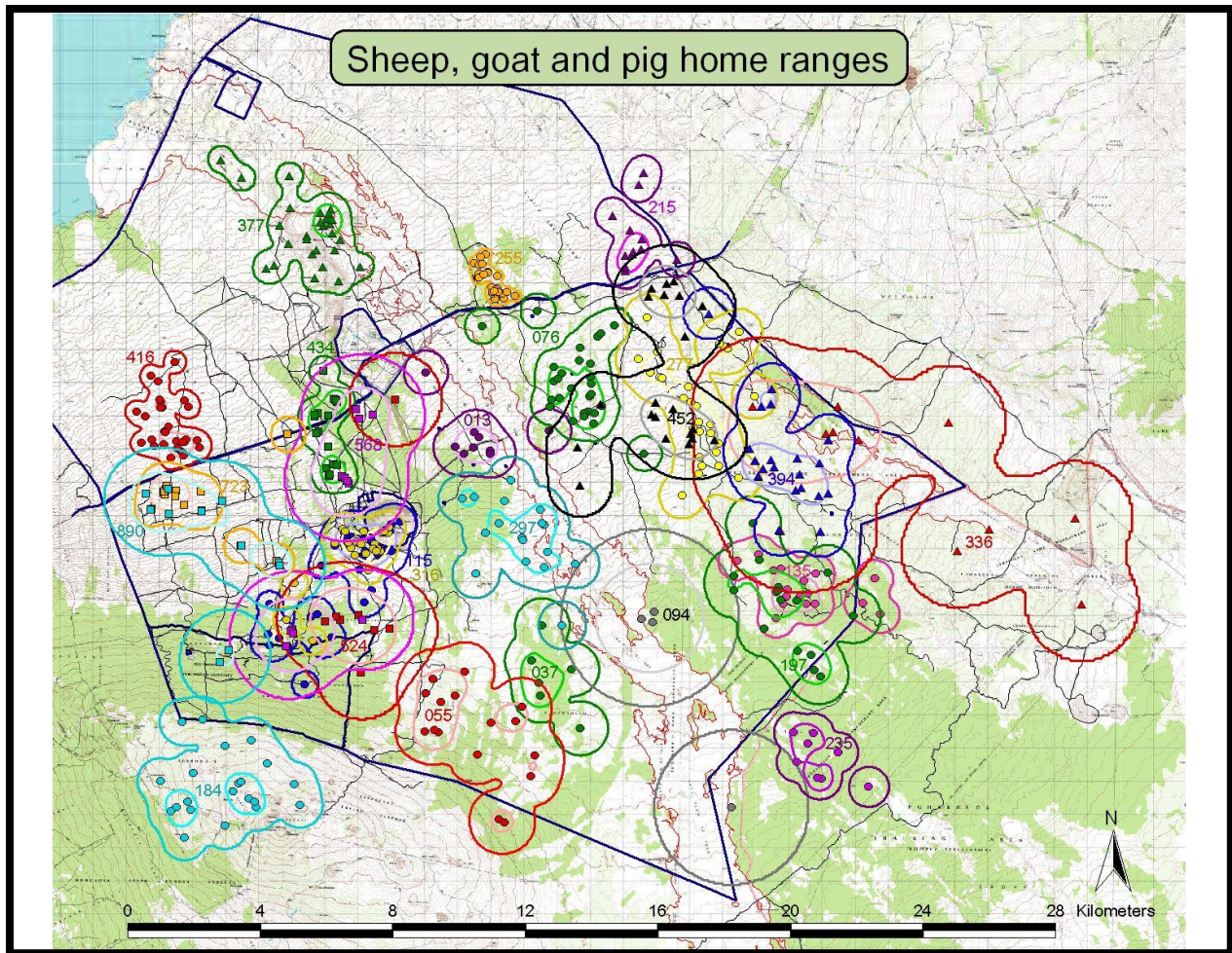


Figure 8.1 Summary of the 95% kernel home range results (km²) for sheep (circles), pigs (squares), and goats (triangles) in the region. Each color signifies an individual animal.

Habitat Use

The sheep in this study generally used well-defined ranges, characterized by repeated movements back and forth across their established ranges. There were no instances of clear dispersal from one area to another, though the majority of sheep radio-collared were >1 year in age. In fact, two sheep (Ram 184 and Ewe 115) were translocated 1 and 2 km, respectively, from their capture sites and released within the Forest Bird Sanctuary. However, both animals quickly left the Sanctuary and returned to their former home ranges. Sheep were found more frequently in open areas during the morning and late afternoon periods, feeding in small herds. On cloudy days, sheep tended to remain in more open areas for longer periods. During the hottest portion of the day sheep were often found bedded down beneath the shade of trees or shrubs.

Due to unusually high rainfall during our study, there was abundant grass and herbaceous vegetation for sheep to feed on. We detected some browsing on bark and woody vegetation, but apparently at lower levels than in the past, based on the condition and prevalence of past bark stripping that we observed.

Herd composition

Herd composition among sheep and goats was very fluid throughout the year, and from day to day. Some animals, especially goats, were found in large herds on several occasions. However, herd size and composition was nearly always changed from one observation to the next. Sheep showed some change in herd composition during the fall lambing season, with ewes breaking out of larger herds and forming into smaller herds composed of only ewes and lambs. During this period, small bachelor herds of rutting rams were occasionally seen. Pigs tended to be more solitary or associated with their littermates.

9.0 APPENDIX B: LIST OF SPECIES IN THE PLAN AREA

The Pu‘u Wa‘awa‘a Management Plan (2003) includes a list of threatened and endangered species currently known to exist within the area, as well as a list of species historically known to occur in the area, and those likely to be suited to the area. Endangered and threatened species currently existing in the Plan Area (modified from the Management Plan (2003a:63-65) to include Pu‘u Anahulu) are listed in Table 9.1. This list includes both plant and animal species. Note that not all of the listed plants are likely to be negatively impacted by covered activities, particularly those occurring in the Forest Bird Sanctuary portion of the Plan Area.

Protected species which were known to be in the Plan Area historically (from Management Plan (2003a:66), modified to include data from HCP surveys), are included in Table 9.2. A list of additional species that are likely to benefit from mitigation efforts under the Habitat Conservation Plan, but not included as Covered Species, are also listed in Table 9.3. Benefit gained for these species is considered a ‘net benefit’ for the purposes of this HCP, and contribute to the purposes of HRS §195D.

Table 9.1 Endangered and threatened species currently existing in the Plan Area (modified from Management Plan 2003a:63-65 to include Pu‘u Anahulu species). *Indicates species not found during HCP botanical surveys.

Scientific name	Common name	Status
Plants		
<i>Asplenium peruvianum</i> var. <i>insulare</i>		Endangered
<i>Chrysodracon hawaiiensis</i>	Hala pepe	Endangered
<i>Colubrina oppositifolia</i>	Kauila	Endangered
<i>Haplostachys haplostachya</i>	Honohono	Endangered
<i>Hibiscus brackenridgei</i> ssp. <i>brackenridgei</i>	Ma‘o hau hele	Endangered
<i>Kokia drynarioides</i>	Koki‘o	Endangered
<i>Mezoneuron kavaianse</i>	Uhiuhi	Endangered
<i>Neraudia ovata</i>		Endangered
<i>Nothoestrum breviflorum</i>	‘Aiea	Endangered
<i>Phyllostegia velutina</i>		Endangered
<i>Portulaca sclerocarpa</i>	Po‘e	Endangered
<i>Silene lanceolata</i>	Hawaiian catchfly	Endangered
<i>Solanum incompletum</i>	Pōpolo kū mai	Endangered
<i>Stenogyne angustifolia</i>	Creeping mint	Endangered
<i>Vicia menziesii</i>	Hawaiian vetch	Endangered
<i>Zanthoxylum dipetalum</i> var. <i>tomentosum</i>	A‘e	Endangered
<i>Zanthoxylum hawaiiensis</i>	A‘e	Endangered
<i>Acacia koaia</i>	Koai‘a	Species of Concern
<i>Alphitonia ponderosa</i>	Kauila	Species of Concern

Scientific name	Common name	Status
<i>Capparis sandwichiana</i>	Maiapilo	Species of Concern
<i>Euphorbia olowaluana</i>	‘Akoko	Species of Concern
<i>Eragrostis deflexa</i>		Species of Concern
<i>Exocarpus gaudichaudii</i>		Species of Concern
<i>Fragaria chiloensis</i>		Species of Concern
<i>Melicope hawaiiensis</i>	Manena	Species of Concern
<i>Polyscias sandwicensis</i>	‘Ohe makai	Species of Concern
<i>Sisyrinchium acre</i>	Mau‘u lā ‘ili	Species of Concern
<i>Stenogyne macrantha</i>		Species of Concern
<i>Tetramalopium consanguineum</i>		Species of Concern
<i>Tetramalopium humile</i>		Species of Concern
Vertebrates		
<i>Branta sandvicensis</i>	Nēnē (Hawaiian goose)	Endangered
<i>Buteo solitarius</i>	‘Io (Hawaiian hawk)	Endangered
<i>Eretmochelys imbricata</i>	Honu ‘Ea (Hawksbill turtle)	Endangered
<i>Himantopus mexicanus knudseni</i>	Ae‘o (Hawaiian stilt)	Endangered
<i>Lasiurus cinereus semotus</i>	‘Ōpe‘ape‘a (Hawaiian hoary bat)	Endangered
<i>Loxops coccineus coccineus</i>	‘Akepa	Endangered
<i>Oreomystis mana</i>	Hawai‘i creeper	Endangered
<i>Chelonia mydas</i>	Honu	Endangered
<i>Asio flammeus sandwichensis</i>	Pueo	Species of Concern
Invertebrates		
<i>Manduca blackburni</i>	Blackburns’s sphinx moth	Endangered
<i>Drosophila heteroneura</i>		Endangered
<i>Anomis vulpicolor</i>		Species of Concern
<i>Caconemobius varius</i>		Species of Concern
<i>Coleotichus blackburniae</i>		Species of Concern
<i>Ectemnius rubrocaudatus</i>		Species of Concern
<i>Hylaeus coniceps</i>		Species of Concern
<i>Hylaeus difficilis</i>		Species of Concern
<i>Hylaeus filicum</i>		Species of Concern
<i>Hylaeus hula</i>		Species of Concern
<i>Hylaeus kona</i>		Species of Concern

Scientific name	Common name	Status
<i>Hylaeus laetus</i>		Species of Concern
<i>Hylaeus pubescens</i>		Species of Concern
<i>Micromus usingeri</i>		Species of Concern
<i>Oliarus lorettae</i>		Species of Concern
<i>Omiodes monogona</i>		Species of Concern
<i>Plagithmysus mezoneuri</i>		Species of Concern
<i>Plagithmysus elegans</i>		Species of Concern
<i>Plagithmysus simplicollis</i>		Species of Concern
<i>Rhyncogonus giffardi</i>		Species of Concern
Snails		
<i>Leptachatina lepida</i>		Species of Concern
<i>Neritilia hawaiiensis</i>		Species of Concern
<i>Vitrina tenella</i>		Species of Concern
<i>Metabetaeus lohena</i>		Species of Concern

Table 9.2 Endangered and threatened species historically found in the Plan Area (from Management Plan 2003a modified to include data from HCP surveys).

Scientific name	Common name	Status
Plants		
<i>Bidens micrantha</i> subsp. <i>ctenophylla</i> *	Ko'oko'olau	Endangered
<i>Bonami menziesii</i>		Endangered
<i>Delissea undulata</i> ssp. <i>undulata</i>		Endangered
<i>Diellia erecta</i>		Endangered
<i>Gardenia brighamii</i>	Nānū	Endangered
<i>Hibiscadelphus hualalaiensis</i>	Hau kuahiwi	Endangered
<i>Isodendrion pyriformis</i>	Wahine noho kula	Endangered
<i>Ochrosia kilaueaensis</i>	Hōlei	Endangered
<i>Phyllostegia racemosa</i>	Kiponapona	Endangered
<i>Plantago hawaiiensis</i> *	Laukahi kuahiwi	Endangered
<i>Cryptandra menziesii</i> *	Ha'iwale	Species of Concern
<i>Dissochondrus biflorus</i>		Species of Concern
<i>Nesoluma polynescium</i>	Keahi	Species of Concern
<i>Phytolacca sandwicensis</i> *	Pōpolo kū mai	Species of Concern

Scientific name	Common name	Status
<i>Rubus macraei</i> *	‘Akala	Species of Concern
<i>Sicyos macrophyllus</i> *	‘Anunu	Proposed Endangered
Vertebrates		
<i>Anas wyvilliana</i>	Koloa	Endangered
<i>Corvus hawaiiensis</i>	‘Alalā	Endangered
<i>Hemignathus munroi</i>	‘Akiapola‘au	Endangered
<i>Pterodroma phaeopygia sandwicensis</i>	‘Ua‘u	Endangered
Invertebrates		
<i>Partulina confusa</i>		Species of Concern

Table 9.3 Endangered, threatened, and common species likely suited for restoration efforts in the Plan Area not covered under this HCP (Modified from Management Plan 2003a:67-68).

Scientific name	Common name	Status
Plants		
<i>Abutilon menziesii</i>	Ko'oloa'ula	Endangered
<i>Achyranthes mutica</i>		Endangered
<i>Cyperus faurei</i>		Endangered
<i>Fluggea neowawraea</i>	Mēhamehame	Endangered
<i>Gouania vitifolia</i>		Endangered
<i>Hedyotis coriacea</i>	Kio'ele	Endangered
<i>Isodendrion hosakae</i>	Aupaka	Endangered
<i>Isodendron pyrifolium</i>	Wahine noho kula	Endangered
<i>Lipochaeta venosa</i>	Nehe	Endangered
<i>Pritchardia affinis</i>	Loulu	Endangered
<i>Sesbania tomentosa</i>	'Ohai	Endangered
<i>Spermolepis hawaiiensis</i>		Endangered
<i>Tetramolopium arenarium</i> var. <i>arenarium</i>		Endangered
<i>Vigna o-wahuensis</i>		Endangered
<i>Silene hawaiiensis</i>		Threatened
<i>Ranunculus hawaiiensis</i>		Candidate
<i>Bidens campylotheca</i> ssp. <i>Campylotheca</i>		Species of Concern
<i>Bobea timonioides</i>	'Ahakea	Species of Concern
<i>Dissonchondrous biflorus</i>		Species of Concern
<i>Festuca hawaiiensis</i>		Candidate
<i>Phyllostegia stachyoides</i>		Candidate
<i>Acacia koa</i>	Koa	None
<i>Alyxia olivaeformis</i>	Maile	None
<i>Antidesma pulvinatum</i>	Hame	None
<i>Diplazium sandwichianum</i>	Hō'i'o	None
<i>Bidens menziesii</i>	Ko'oko'olau	None
<i>Canavalia hawaiiensis</i>	'Āwikiki	None
<i>Charpentiera obovata</i>	Pāpala	None
<i>Cheirodendron trigynum</i>	'Olapa	None
<i>Chenopodium oahuense</i>	'Āweoweo	None
<i>Cibotium</i> spp.	Hāpu'u	None
<i>Claoxylon sandwicense</i>	Po'ola	None

Scientific name	Common name	Status
<i>Clermontia clermontioides</i>	‘Ōha wai	None
<i>Cocculus trilobus</i>	Huehue	None
<i>Coprosma cymosa</i>	Pilo	None
<i>Diospyros sandwicensis</i>	Lama	None
<i>Dodonaea viscosa</i>	‘A‘ali‘i	None
<i>Dryopteris spp.</i>		None
<i>Dubautia linearis</i>	Na‘ene‘e	None
<i>Dubautia plantaginea</i>	Na‘ene‘e	None
<i>Eragrostis atropioides</i>	Lovegrass	None
<i>Eragrostis leptophylla</i>		None
<i>Hesperocnide sandwicensis</i>		None
<i>Lipochaeta subcordata</i>	Nehe	None
<i>Metrosideros polymorpha</i>	‘Ōhi‘a	None
<i>Myrsine lanaiensis</i>	Kōlea	None
<i>Myrsine lessertiana</i>	Kōlea lau nui	None
<i>Nephrolepis exaltata</i>	Swordfern	None
<i>Nestegis sandwicensis</i>	Olopuā	None
<i>Nototrichium sandwichensis</i>	Kulu‘i	None
<i>Peperomia cookiana</i>	‘Ala‘ala‘wai nui	None
<i>Peperomia leptostachya</i>	‘Ala‘ala‘wai nui	None
<i>Peperomia macraei</i>	‘Ala‘ala‘wai nui	None
<i>Phyllostegia ambigua</i>	Mint	None
<i>Phytolacca sandwicensis</i>	Pōpolo	None
<i>Pisonia brunoniana</i>	Pāpala	None
<i>Pisonia sandwicensis</i>	Pāpala	None
<i>Pittosporum hosmeri</i>	Hō‘awa	None
<i>Pittosporum terminaloides</i>	Hō‘awa	None
<i>Plumbago zeylandica</i>	‘Ilie‘e	None
<i>Polystichum hillbrandii</i>		None
<i>Pouteria sandwicensis</i>	‘Āla‘a	None
<i>Psychotria hawaiiensis</i>	Kōpiko	None
<i>Psydrax odoratum</i>	Alahe‘e	None
<i>Rauwolfia sandwicensis</i>	Hao	None
<i>Rumex giganteus</i>	Pāwale	None

Scientific name	Common name	Status
<i>Sadleria</i> spp.	‘Ama‘u	None
<i>Santalum paniculatum</i>	‘Iliahi	None
<i>Senna gaudichaudii</i>	Kolomona	None
<i>Sicyos lasiocephalus</i>		None
<i>Sophora chrysophylla</i>	Māmane	
<i>Streblus pendulinus</i>	A‘ia‘i	None
<i>Urera glabra</i>	Ōpuhe	None
<i>Wikstroemia</i> spp.	‘Ākia	None
<i>Xylosma hawaiiense</i>	Maua	None

10.0 APPENDIX C: EXCLOSURE STUDY

In September 2004, a study was initiated to quantify the effectiveness of exclosures in minimizing direct negative impacts from ungulates on plant species in the Plan Area, and to document the effect of browsing/grazing on plant performance (i.e. reproduction and growth). *Stenogyne angustifolia* is used here as an example to understand the effects game mammals have on native plant species.

10.1 METHODS

For each species, an exclosure (approximately 20 m by 20 m, four ft hogwire fencing) and a corresponding unfenced control site were established. For Hawaiian Catchfly and *Stenogyne angustifolia*, both the exclosure and the corresponding control sites were monitored at 0, 6, 12, and 24 months from initiation of the study, and Honohono and *Phyllostegia velutina* were monitored at 0, 6, 12, and 18 months from initiation of the study. The variation in monitoring intervals is the result of accessibility issues for the various field sites.

Each site was divided into four sampling quadrants and each of the four species were labeled and flagged. For each individual plant, the following attributes were measured and recorded: height (cm), width (cm), reproductive status (flowers present, fruit present, or n/a), age (seedling or mature), survival, vigor, and signs of ungulate damage (browse activity including evidence of broken stems or twigs, soil disturbance, and/or trampling).

10.2 RESULTS

10.2.1 Changes in Level of Browsing

A comparison of control (non-fenced) plants to populations of the *Stenogyne angustifolia* protected with game fencing showed a marked decrease in the amount of ungulate damage in the fenced populations over time (Figure 10.1). Browse activity was between 20-30% in both fenced and unfenced units at the beginning of the study. However, it is important to note that at the 18 months monitoring point, approximately 20% of the plants showed browse activity within the fencing unit, indicating ungulate ingress. This exemplifies the point that fences are not fool proof and need to be monitored for ungulate ingress.

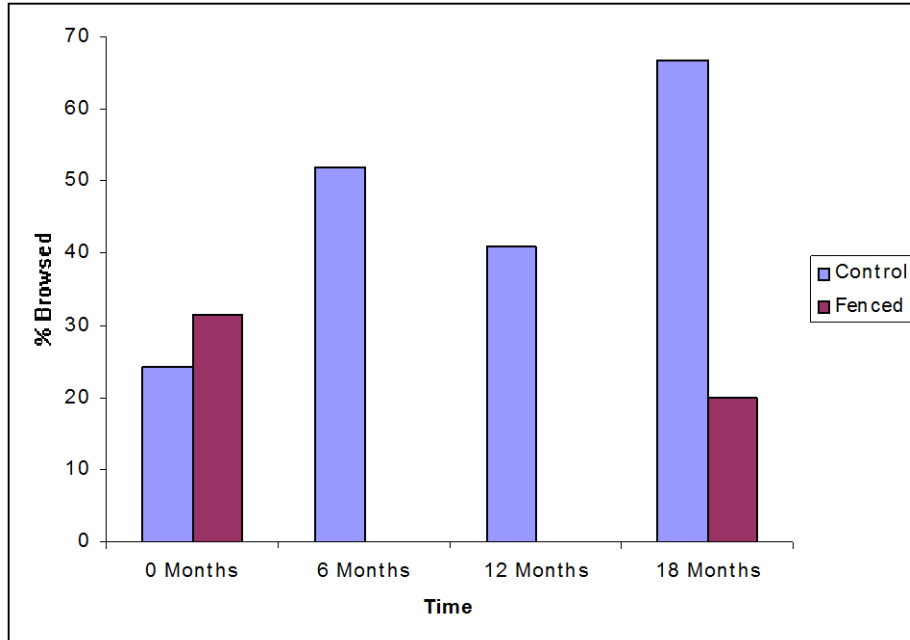


Figure 10.1 Percent ungulate browse activity on *Stenogyne angustifolia* over the 18 month study period.

10.2.2 Changes in Plant Growth

Monitoring of growth (as measured by plant width) showed a similar positive impact within the exclosures, where plant growth is markedly higher in fenced individuals of *Stenogyne angustifolia* versus unfenced (Figure 10.2).

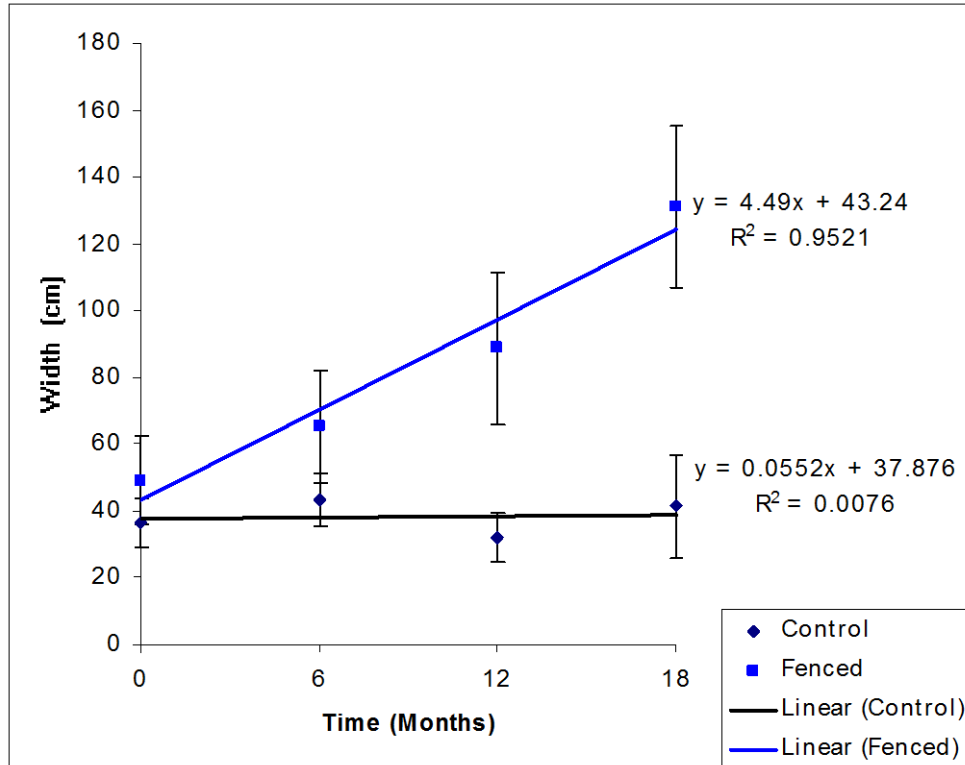


Figure 10.2 Scatter plot of *Stenogyne angustifolia* plant width over time in both fenced and unfenced units.

10.2.3 Changes in Reproductive Rates

A comparison of the percent of reproductive individuals (plants with flowers, buds, or fruits) of *Stenogyne angustifolia* indicates over 70% of individuals in the exclosures were reproductive after one year, compared to 30% of individuals outside of exclosures (Figure 10.3).

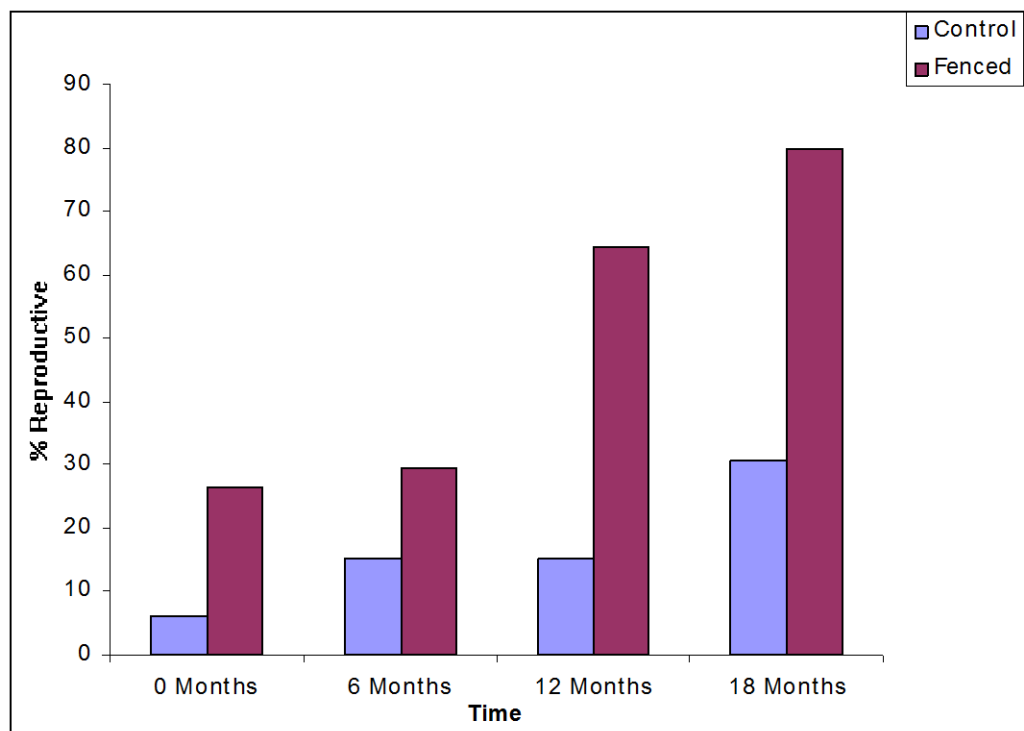


Figure 10.3 Percent of *Stenogyne angustifolia* individuals reproducing over 18 months of the ungulate exclosure study.

10.2.4 Discussion and Conclusions

The study of the effects of exclosures on minimizing direct negative effects of grazing provides evidence that exclosures effectively minimize browsing, resulting in increased plant growth and reproduction.

Exclosure plants exhibited positive growth while the unfenced individuals showed no growth. Exclosure plants exhibited significantly greater reproductive rates compared to their non-protected counterparts. It is important to note, however, that some exclosures eliminated ungulate browse, but in other cases simply minimized browse because of ungulate ingress.

Results of this study suggest that exclosures are highly effective means of minimizing negative impacts from grazing mammals on native plants at Pu‘u Wa‘awa‘a and Pu‘u Anahulu. The lower reproductive effort exhibited by control site plants suggests that replacement may not be sufficient to replace senescence in unprotected areas. Improved reproductive rates of plants in exclosure populations may be critical to population survival and species recovery.

11.0 APPENDIX D: BLACKBURN'S SPHINX MOTH SURVEYS AND RESULTS

11.1 SURVEY METHODS

In order to determine potential impacts to *M. blackburni* from Plan activities and minimize take, we initiated surveys for eggs, larvae, and adult moths and documented host plant use to estimate density and distribution of *M. blackburni* within the Plan Area. We also considered the surveys a way to contribute to our knowledge of the species, and to identify factors which could be manipulated to increase benefit and reduce threats to the species. Density and distribution of *M. blackburni* is known to vary within the Plan Area (E. Adkins and C. King, observation). The purpose of the surveys were to quantify *M. blackburni* density and distribution on tree tobacco (*Nicotiana glauca*), an invasive plant host, and attempt to identify significant factors affecting density and distribution such as plant density, leaf density, plant height, and elevation. Survey methods focused on determining the abundance of eggs, larvae, and adults because of potential differences in distribution, timing, and effective survey strategies for these different life stages. These data were used to determine estimated levels of take due to clearing of the invasive tree tobacco, to increase the effectiveness of mitigation efforts, and to estimate benefit from planned mitigation efforts. Field methods, analyses and results are described in this section.

11.1.1 Tree Tobacco Distribution on Roadsides and Fuelbreaks

To quantify the distribution of tree tobacco on roadsides and fuelbreaks across the Plan Area, locations of tree tobacco were recorded using Global Positioning System (GPS) technology as HCP staff drove 4x4 roads. For each location, we recorded the number of tree tobacco along a 25 m x 3 m belt transect with the following categories: low (1-9 plants), medium (10-19 plants), or high (> 20 plants). These locations were used to create a preliminary map of tree tobacco distribution across the Plan Area (Figure 11.1). While this method was not comprehensive in that it didn't cover all of the known roads within the Plan Area, the sampled area was large enough that it gave a general picture of the likely distribution and density of tree tobacco across the entire Plan Area. The initial survey was completed in 2010 and more comprehensive surveys were conducted again in 2011 and 2012.

We then used a subset of this data taken in Pu'u Anahulu (Figure 11.1), to calculate what proportion of the roads that are expected to contain tree tobacco actually are occupied by tree tobacco. For a stretch of road 37,402 m long and 7 m wide (261,814 m²), 649 tree tobacco location survey points were recorded. Each survey point represents a 25 m x 3 m long belt transect that contains tree tobacco. For the subset of road used in this calculation, the total area actually occupied by tree tobacco was 48,675 m² or approximately 18.6% of the surveyed roads.

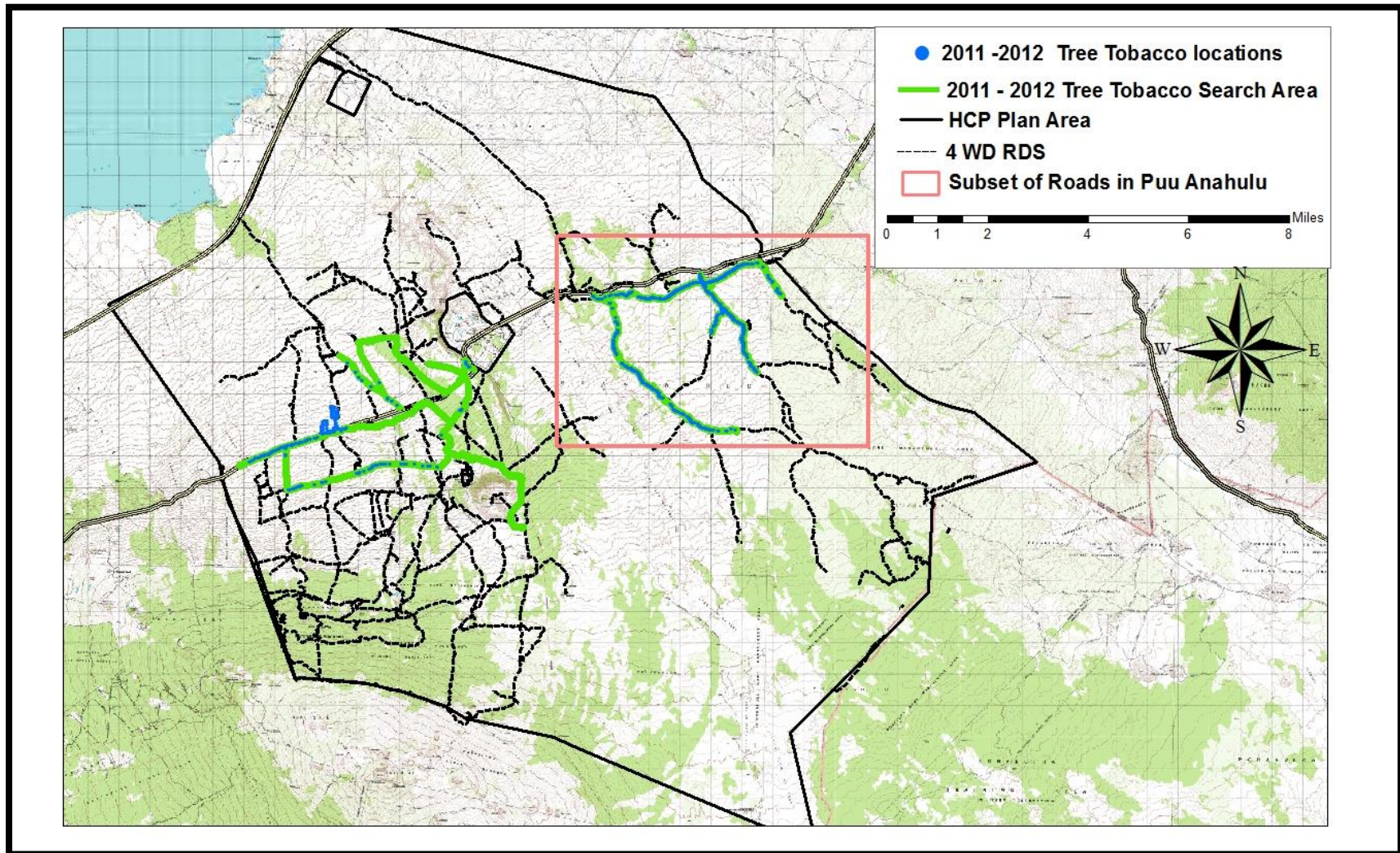


Figure 11.1 2011 and 2012 tree tobacco search area (green line) with mapped tree tobacco locations (blue dots). The area in the red/pink rectangle highlights the subset of roads in Pu'u Anahulu used to calculate the proportion of occupied habitat.

Next, a map of the Core Tree Tobacco Invasion Area (CTTIA) was created to indicate which roads in the Plan Area currently contain, have contained in the past, or may contain tree tobacco in the future (Figure 11.2). Based on this map, we estimate the CTTIA to be 839,486.38 m² or approximately 207 acres. If we assume that the coverage measured above in general characterizes the density of tree tobacco as a whole across the Plan Area (and this is likely a conservative estimate as Pu‘u Anahulu tends to have high density), then we can apply this value to the CTTIA (839,486.38 m² x 0.186), to calculate the area occupied by tree tobacco (Occupied Area = 156,144.467 m²).

11.1.2 *M. blackburni* Larval Density/Distribution on Tree Tobacco

We conducted *M. blackburni* surveys on a portion of the roads, fuelbreaks, and off road areas using visual surveys on belt transects. These belt transects were randomly selected from within areas of known tree tobacco distribution (based on the roadside surveys described above). Each belt transect consisted of a 25 m x 3 m area located on a randomly selected side of the road (left or right side). All individual tree tobacco that occurred within each belt transect were examined for 3 minutes each to search for *M. blackburni* eggs and larvae by trained staff. Data collected included: location (UTM coordinates), dominant vegetation description, elevation, tree tobacco height class (0-1 m, 1-2 m, 2-5 m, >5 m), and leaf density (low, medium, high). We chose to categorize surveyed tree tobacco plants into different height classes and leaf densities because these traits can correlate with factors that are selected for by certain insects as hosts for their offspring (e.g. leaf quality and quantity). In addition, we also recorded the percentage of each plant searched, reproductive status (flowering, fruiting), presence of larval feeding damage, additional insects present, number of *M. blackburni* eggs/host plant, number of larvae/host plant, approximate life stage (instar) of larvae (1st to 5th instar), number and type of predators/parasitoids observed on host plants, and any damage to plant tissue (ungulate browse, trampling, cutting, vehicle, or herbicide spray), because those factors could also affect host site selection by adult moths through their effects on plant quality.

11.2.3 *M. blackburni* Larval Density/Distribution on ‘Aiea

We plan to survey for *M. blackburni* eggs and larvae during HCP implementation on a subset of mapped wild ‘Aiea (*Nothocestrum breviflorum*) throughout the Plan Area. Thorough surveys of ‘Aiea are difficult because the wood is extremely brittle, making the plants impossible to climb, and thus leaving much of the tree inaccessible to searchers. Additionally, many of the trees in the Plan Area are in poor health with reduced foliage (likely due to many factors including drought, insect pests, and competition with invasive plants) which limits the available substrate for the larvae. Where possible, these threats will be controlled around individual ‘Aiea trees (e.g. through removal of invasive weeds). Targeted surveys for *M. blackburni* eggs and larvae on ‘Aiea will be completed during regularly scheduled intervals to be determined during HCP implementation to establish the presence or absence and distribution of the species on the native host plant. Reporting will include the total number and average density of *M. blackburni* eggs and larvae per host plant as well as distribution within the Plan Area.

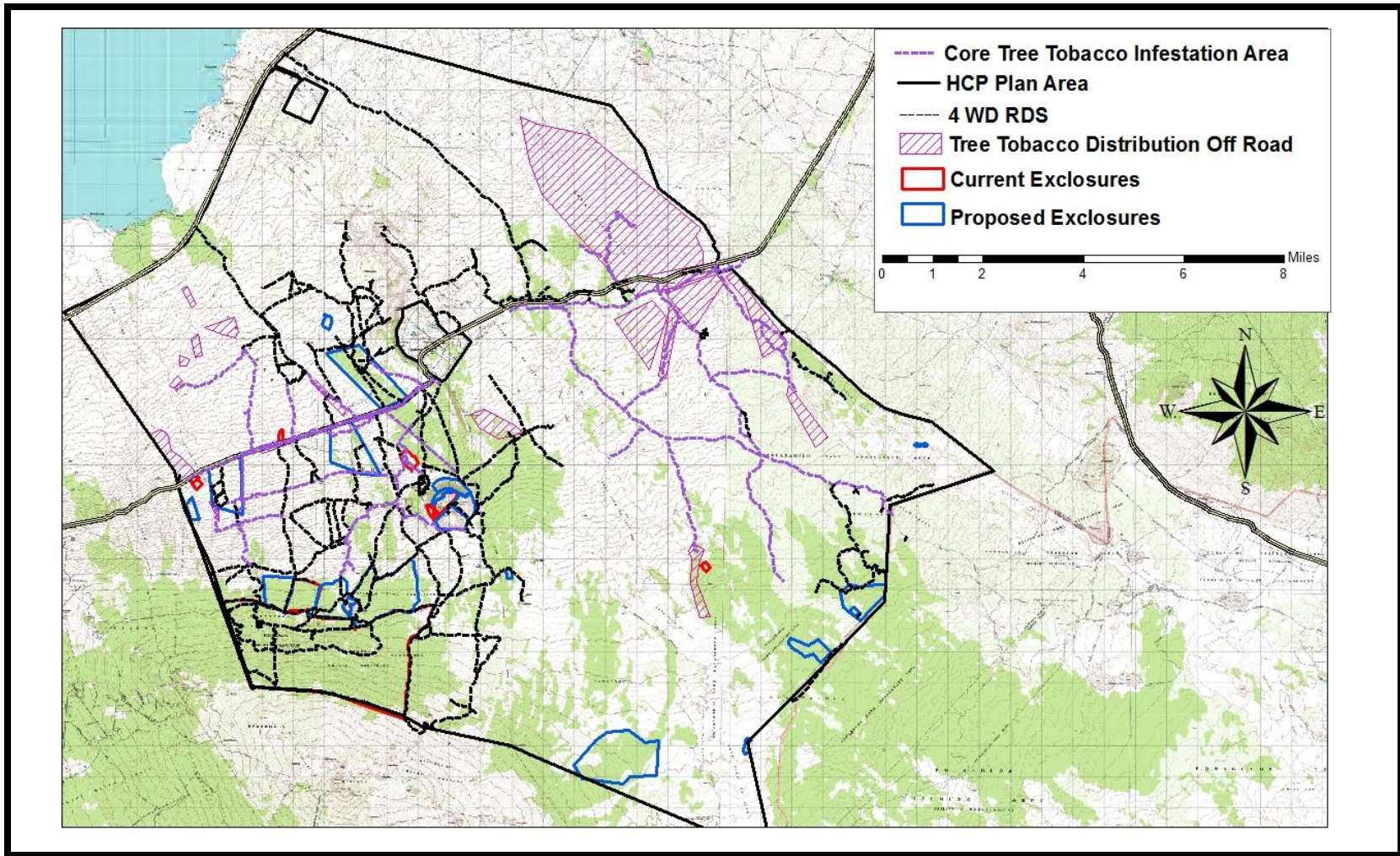


Figure 11.2 Estimated tree tobacco distribution in the Plan Area based on the 2015 helicopter survey (pink hashed area). Roads in purple indicate the Core Tree Tobacco Infestation Area.

In addition, we will also record the number of each life-stage of *M. blackburni* observed, the number of host plants occupied, and the number and type of larval predators and parasitoids seen. Moreover, if we find significant associations between *M. blackburni* use and measured habitat or environmental variables (e.g. plant size and condition, location, substrate, plant community type, etc.), these results will be reported.

11.2.4 Adult *M. blackburni* Surveys:

We used black-light traps to survey for the presence of adult moths at five different locations within the Plan Area on four separate occasions. The vegetation at these survey locations varied between areas dominated by native plants and areas dominated by alien species. Light traps consisted of an 18 inch ultra-violet light bulb (powered by a 12-volt battery) placed in front of a white bed sheet suspended vertically from a clothesline. Individual moths that land on the sheet can be visually identified or photographed. The morphology of the adult *M. blackburni* is unique among moths in Hawai‘i making them easy to identify in the field; they are Hawai‘i’s largest native insect with a wingspan of up to five inches, and they have distinctive spindle shaped bodies with five orange spots along each side of the abdomen (USFWS 2003b). In order to compare adult *M. blackburni* presence and density between various field sites, light trapping was conducted in comparable conditions, on nights with low wind, and during an early moon phase (i.e. new moon). Light traps were deployed for 8 hours following sunset at each trap site.

For future *M. blackburni* surveys conducted during HCP implementation, the total number and distribution of adult *M. blackburni* will be reported for each sampling location, plant community type, elevation, and as Plan cumulative totals.

11.3 RESULTS

11.3.1 Transect Surveys

Belt transect were surveyed for *M. blackburni* over multiple years (2010 – 2012). A total of 196 belt transects were surveyed for *M. blackburni* eggs, larvae and the other variables mentioned above. For all surveys combined, a grand total of 120 larvae, 91 hatched eggs (appears split or has an exit hole), and 101 un-hatched eggs were documented on tree tobacco (Table 11.1).

Table 11.1 Number of transects and plants searched, and the number of larvae and eggs (un-hatched and hatched) found during *M. blackburni* surveys in 2010, 2011, and 2012.

Survey Date	Transects Surveyed	Plants Surveyed	Larvae	Hatched Eggs	Unhatched Eggs
Feb 2010	14	436	55	28	11
Feb 2011	43	1208	38	20	40
Feb 2012	96	2323	26	43	47
Aug 2012	43	1328	1	0	3
Total	196	5295	120	91	101

Environmental Variables

During February 2012, we were able to survey the greatest number of transects to date (a total of 96). Since this is the largest data set we currently have for one sampling period, a more in-depth analysis was performed. We considered whether four factors influenced the presence and absence of Blackburn's sphinx moth eggs and larvae: 1) sampling period 2) plant leaf density, 3) plant height, and 4) plant location (off road or on road). First, we found that the number of *M. blackburni* eggs and larvae depended on the sampling period (Figure 11.3); the number of eggs and larvae found per acre decreased by 56% and 69% respectively between 2011 and 2012 showing that there is substantial year to year variation in abundance. Moreover, within 2012, egg and larvae abundance decreased by 82% and 93% respectively between the wetter (February), and dryer (August) 2012 months, showing that there is substantial variation in abundance between wet and dry seasons, and that dry seasons may be a good time to clear invasive tree tobacco plants off of roadsides and fuelbreaks.

We also found that while a smaller proportion of plants on the landscape fall in to the high leaf size category (only 24.5%), over half of all of the eggs and larvae found (53.8%) were on plants in this category, suggesting that Blackburn's sphinx moth are preferentially selecting plants with relatively large leaves (Figure 11.4). Large-leafed plants tend to be young, and large leaves also tend to be found on older plants that are damaged (such as re-growth from vehicle damage or cutting). Vegetation in re-growth and on young plants may have lowered levels of secondary defense chemicals rendering the leaves more palatable to larvae compared to older plants, or they may simply be selected to a greater degree because of larger surface area for consuming. Another possibility is that there is a greater probability of an adult moth finding plants that have larger leaves.

We also found a greater proportion of plant use by *M. blackburni* with increasing plant size (Figure 11.5); Blackburn's sphinx moth appear to be preferentially selecting plants of a larger size category, in particular those in the 2-5 m size class. In addition to on-road transects, areas perpendicular to the roadsides were also surveyed. We found that roughly the same proportion of plants being used by Blackburn's sphinx moth on the road as off of the road (Figure 11.6).

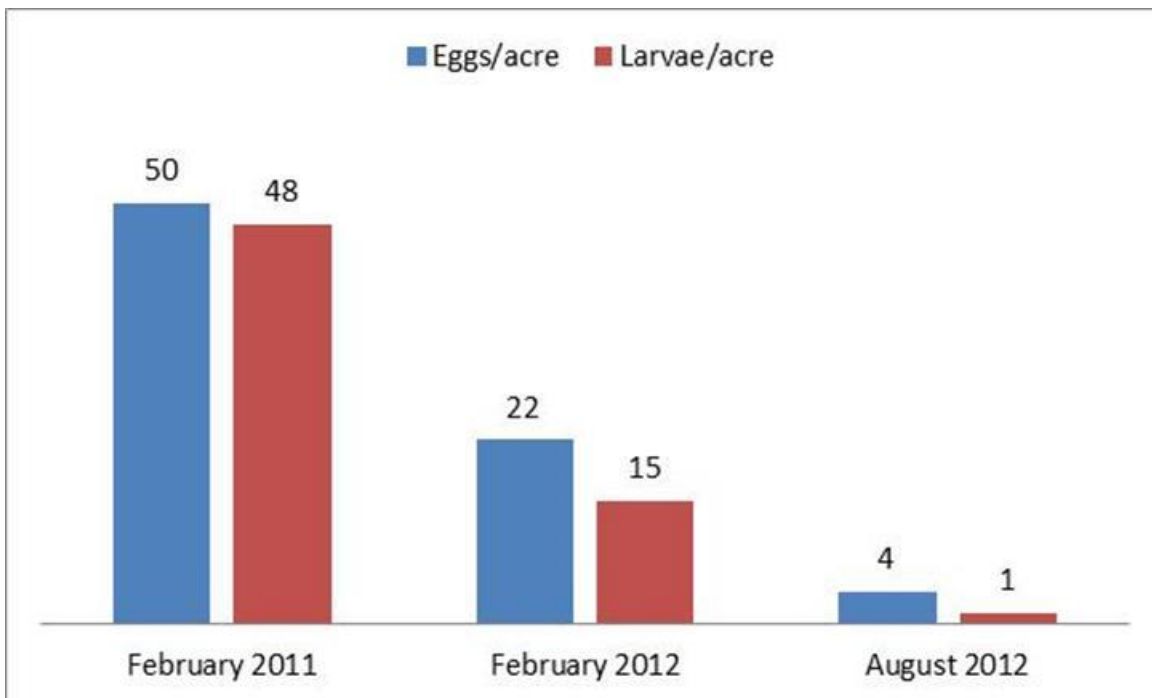


Figure 11.3 Estimate of the number of eggs and larvae per acre of tree tobacco in the Plan Area. Larval surveys were done on transects containing a minimum of 10 trees per 75 m².

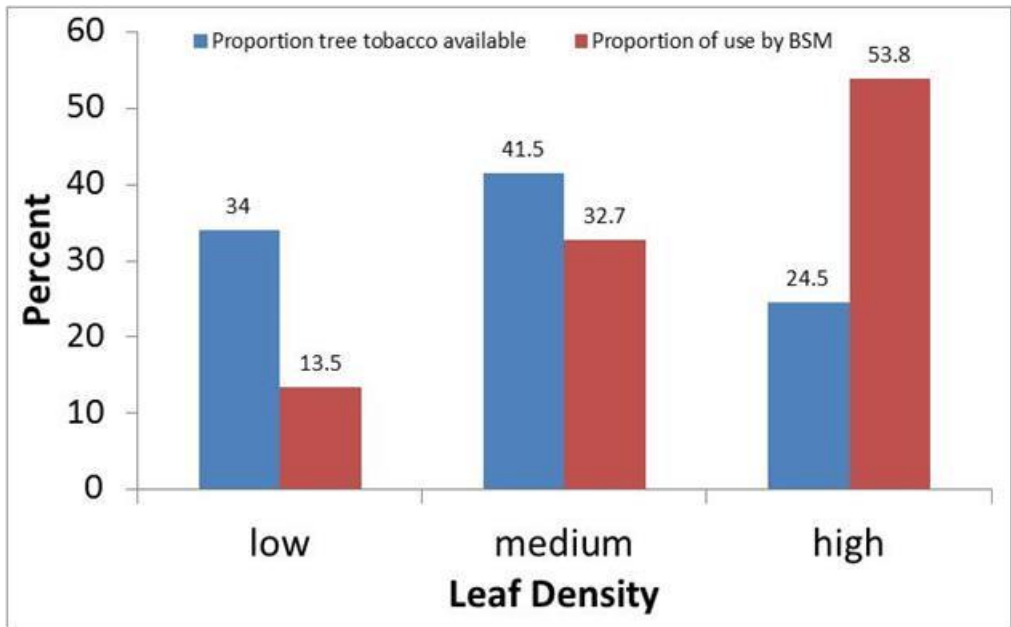


Figure 11.4 Percent of plants containing Blackburn’s sphinx moth eggs and larvae. Blue bars represent the proportion of plants that were available for use by Blackburn’s sphinx moth of each leaf density category (low, medium, and high, all blue bars sum to 100%). Red bars represent the proportion of the plants actually containing eggs and larvae (all red bars sum to 100%).

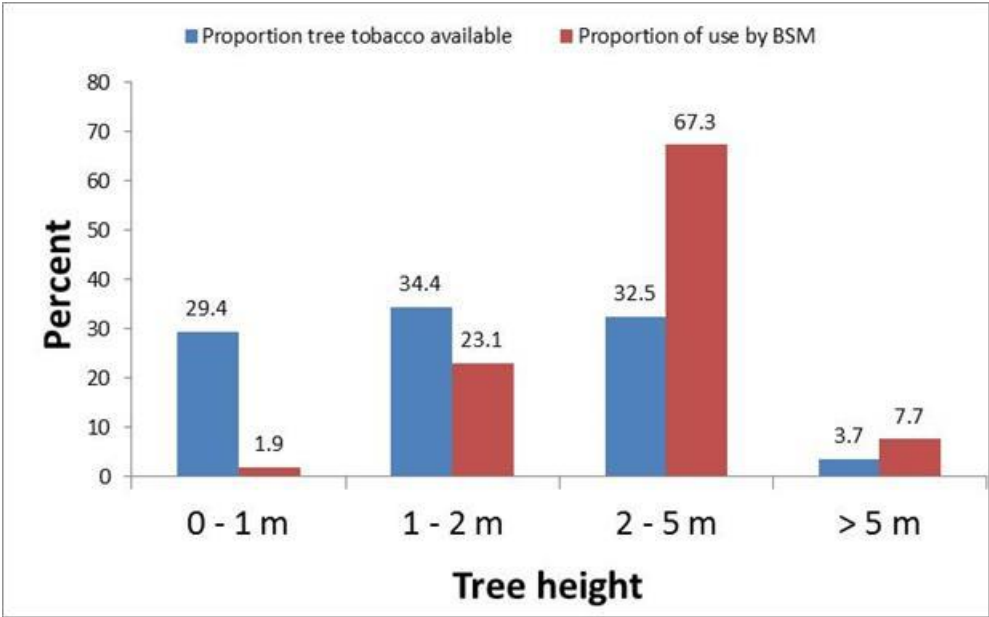


Figure 11.5 Percent of plants in a given size class containing Blackburn’s sphinx moth larvae and eggs. Blue bars represent the proportion of plants available of each of the size classes (blue sums to 100%). Red bars are the proportion of the plants that actually contained eggs and larvae (red sums to 100%).

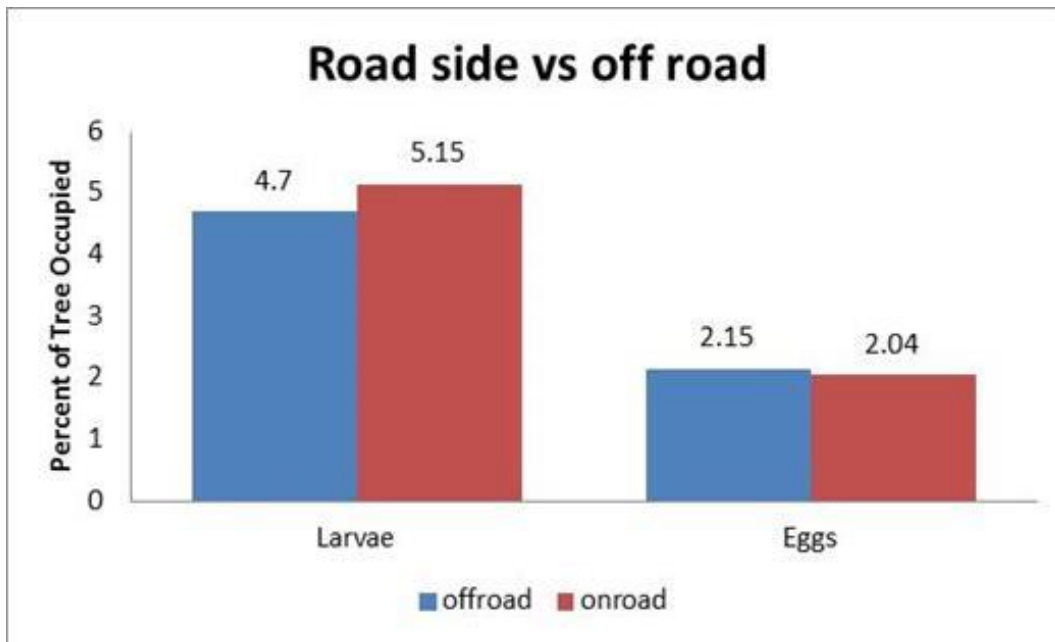


Figure 11.6 A comparison of tree tobacco plants that were occupied by Blackburn’s sphinx moth based on location (on road transects (red bars) or on perpendicular off-road transects (blue bars)).

***Manduca blackburni* larval density/distribution on ‘Aiea**

To date, 17 ‘Aiea trees have been surveyed for *M. blackburni* use. Feeding damage was noted on all individuals surveyed. Larvae and eggs were documented on two individuals, one located makai of the highway in the 13 acre Uhiuhi 1 enclosure and the other in the proposed Henahena enclosure. There have been observations from DOFAW staff of larvae on ‘Aiea on two other instances in recent years, one on a wild individual and the other on an outplant on the Pu‘u Wa‘awa‘a cinder cone.

***M. blackburni* adult density and distribution**

Light trapping was conducted in the Plan Area on four occasions in 2009-2010. In September 2009, two light traps were deployed in a mixed silk oak (*Grevillea robusta*) and ‘Ōhi‘a forest along the road side for 4 hours. One adult moth was documented visiting a trap at about 9:00 PM. From January 11-15, 2010, three light traps were deployed for about 5 hours each, however no adult moths were observed. These light traps were located in three habitat types, 1) a mixed native/alien forest with tree tobacco and ‘Aiea present, 2) a predominantly native forest with ‘Aiea present, and 3) a highly disturbed area dominated by *N. glauca*. Light trapping was conducted on the Pu‘u Wa‘awa‘a cinder cone, in native outplanted habitat with ‘Aiea present in February 2011. Light traps were deployed on 2 nights for about 5 hours each, but no adult moths were observed. It is important to note that the absence of adult *M. blackburni* at light traps does not confirm absence of the species in a given survey area.

Tree Tobacco and Blackburn’s Sphinx Moth Population Estimate in the Plan Area

We estimated the location and distribution of tree tobacco in the Plan Area based on a helicopter survey conducted in January 2015 (see Figure 11.2). During the helicopter survey, track files and waypoints were taken to map the outer edges of infestation areas as well as map individual tree tobacco locations in less colonized areas. Based on this survey, we estimate that approximately 6,462 acres of the Plan Area (outside of roads) contain tree tobacco (6% of the Plan Area). The winter 2012 off-road BSM survey data was then used to estimate BSM density. A total of 17 Blackburn’s sphinx moth detections (larvae and unhatched eggs) were found on 557 tree tobacco plants across 38 transects. One transect has an area of 75 m² (25 m x 3 m). Using these data, we calculated: the area surveyed as 2850 m² (38 x 75 m²) and BSM

density as 0.006 BSM/m² (17/2850 m²) or 24.1 BSM per acre. Based on the tree tobacco distribution estimated above, the population estimate for Blackburn's sphinx moth larvae and un-hatched eggs outside of roads is 155,734 BSM (24.1 x 6462 = 155,734.2).

An on-road estimate was calculated based on a total of 56 Blackburn's sphinx moth detections (larvae and un-hatched eggs) found on 1766 tree tobacco plants across 80 transects. One transect has an area of 75 m² (25 m x 3 m). Using these data, we calculated: the area surveyed as 6000 m² (80 x 75 m²) and BSM density as 0.009 BSM/m² (56/6000 m²) or 37.8 BSM per acre. Based on the Occupied Area calculated above (38.6 acres), estimated take for one winter clearing period rounds up to 1458 Blackburn's Sphinx moth individuals (37.77 x 38.6 = 1457.9 larvae plus un-hatched eggs). We then added the winter 2012 on-road population estimate (1458 BSM) to the Off-road estimate for a total winter Blackburn's sphinx moth population estimate of 157,445 individuals (larvae plus un-hatched eggs).

12.0 APPENDIX E: PROTOCOLS FOR COLLECTING & HANDLING NATIVE HAWAIIAN PLANTS (HRPRG)

What do I need to provide to the propagation facilities when I submit my samples?

1. Provide whenever possible the Rare Plant Field Data Form. If not, include with plant material sample descriptors such as:
 - Genus, species, subspecies, etc.
 - Collection organization
 - Collector
 - Date of collection
 - Collection site (NAD 83 zone 5 UTM coordinates)
 - Collection number
 - Type of material
 - Purpose of collection
2. Label all samples legibly and unambiguously. Make sure all samples are tagged.
3. If any special or significant sampling methods were used, note what was done.
4. Note any pest problems associated with the parent plant at the time of collection.
5. If possible, make arrangements with the propagation facility before sample collection.
6. Submit samples to the propagation facilities as soon as possible! Delays may have deleterious effects on sample viability.

How do I handle my plant samples after I collect them?

1. Insulate from heat. Keep at ambient or cool temperatures but do not freeze.
2. Try to cushion material so it won't be crushed.
3. Do not pack samples with excessive moisture or allow samples to sweat in the bags for an extended period of time. This promotes fungal and bacterial growth and accelerates the decline of sample quality.
4. Send to propagative facilities as soon as possible.

Collecting and Handling of Seed Propagules

Seed quality is primarily dependent upon the seed collector's methods and post-harvest handling of material. Knowledge of timing and habit of natural seed dispersal is helpful (though not always available) in seed collection. Attention to inflorescence structure and their seed maturity patterns are also important in determining what to harvest.

Loss of seed viability is due to:

1. Excessive temperature.
2. Development of anaerobic conditions around the seeds caused by their own respiration. This is due to storing in plastic bags or tight packing.
3. Prolonged time interval from collection of samples to propagative facilities under conditions conducive to fungal and bacterial growth. Samples of fleshy fruit stored in plastic bags should be aerated intermittently if immediate delivery is not possible.

Dry dehiscent

Only available before it disperses. Try to harvest just before dehiscing.

Dry Indehiscent

Collection and handling is dependent upon when and how they are dispersed. For example, wind dispersed, by animals or insects, etc.

Fleshy fruits

Need to know if recalcitrant (desiccation intolerant) or orthodox (desiccation tolerant).

Recalcitrant Seed

Recalcitrant seeds cannot withstand any drying, have some seed coats adapted to prevent excessive water loss while others have no such adaptation and are prone to rapid water loss post-harvest. In fleshy fruits, high seed moisture can be maintained by keeping the fruit intact. Their individual seeds can be stored in impermeable plastic bags, but must be aerated by opening the bag intermittently to compensate for the restrictive gas exchange environment. Insulate against heat and temperature extremes. Try to maintain a temperature as close to ambient as possible. In mature fruit, indicate if picked off the ground or parent plant. Try not to collect from the ground if possible, unless it is known that they have recently fallen.

Orthodox Seed

In general, the desiccation tolerance of orthodox seed varies throughout its development. They tend to be intolerant of drying during early development and become more tolerant as the seeds mature. If the fruits are immature, leave the seed within the fruit. Treat in the same manner as recalcitrant seeds. Mature seeds from dry indehiscent or dehiscent fruits can be kept in permeable containers such as paper or cloth bags.

Collecting and Handling of Vegetative Propagules

Successful propagation of vegetative propagules are dependent upon many different factors such as the vigor of the parent, the collection date and even the environmental conditions at the time of collection. Correct handling of vegetative material is also important.

1. Vegetative materials deteriorate quickly post-harvest and quick transfer from field to the propagative facility is imperative to ensure maximum viability.
2. Additional care must be taken during transport since they are easily damaged.
3. Place under cool conditions, such as a cooler with ice packs, as soon as possible after collecting and during transport to the propagation facility.
4. Try to collect samples that are insect and disease free.
5. Minimize damage during harvesting and transport.
6. In the case of vegetative cuttings, cut ends can be wrapped in damp towels or newspaper.

Vegetative Cuttings (Herbaceous)

The shoots harvested should be from the last mature flush of the plant. Cuttings should be long enough to allow for trimming and possible division.

If the plant species is known to be hard to propagate, small rooted plant suckers with some of the soil surrounding the roots could be taken if possible. Whole plants should not be removed at any time.

Vegetative Cuttings (Woody)

Propagation of mature trees is more difficult in general than their juvenile counterparts; but in many cases, juvenile forms are not available for collection. Whenever possible, the best material for propagation is the juvenile form. If only mature forms are available, material from their juvenile gradients may have a better chance of success.

Roots and Tubers

Timing of collection is important. The collection of immature or sprouting storage organs can result in significant losses in viability. In the case of plants that possess a dormant stage, a two-visit strategy may be required. One to identify individual clones and mark their location and another to collect the tubers or rhizomes once the top of the plant has died.

Fern Fronds

Fern fronds should be kept in plastic bags and not allowed to dry out during transport. If immediate delivery to the laboratory is difficult, place frond between 2 sheets of paper and allow to air dry flat within a plastic bag propped open. Spores will fall off frond as it dries. Seal the bag shut when completely dry and maintain a flat position to keep the spores on the paper surface.

Flowering Shoots

Some flowering shoots contain vegetative buds that do not develop but remain dormant. Sometimes the dormancy can be broken to produce juvenile vegetative shoots. Also, the immature flowers of a few tree species have been known to form adventitious shoots.

Root Cuttings

When lateral shoots are not available, such as in palms and other monocots, it is sometimes possible to produce vegetative shoots from root cuttings. Roots are often considered to be more juvenile in age than most of the tree. A juvenile gradient exists for roots, with the most juvenile material being closest to the trunk. Sprouts arising naturally from the roots of trees generally are juvenile in form. Store root cuttings in a moist sterile medium, such as peat moss.

Decontamination of Collecting Tools

Many of the Hawaiian endemic species have limited or non-existing *ex situ* collections, which necessitates the need for active *in situ* collecting. It is imperative that precautions be taken to keep the natural populations as disease free as possible. This is not only to maintain clean propagative stock material during collections, but also to ensure the integrity and overall health of the existing population and the surrounding flora. While absolute elimination of all pathogens is impractical and impossible, procedures should be directed toward preventing the introduction of serious foreign pathogens. The risk of disease transmission of viral, fungal, or bacterial origin is a realistic possibility through the cutting implements used in collection of plant samples. Whenever possible, plant cuttings should be made with a new, unused blade. This can be accomplished by using an implement such as a box knife fitted with a disposable razor blade. The used blade can be changed before cutting the next sample. Dr. Stephen Ferreira at UH Plant Pathology has also suggested that any cutting of plant propagules performed post collection should be done with disinfected tools. This is to prevent any disease contamination of the propagules before it goes to the propagation facility.

Decontaminate tools

Make a 5 % to 10% solution of household bleach (such as Clorox manufactured by The Clorox Co.) and soak tools. Let sit for 2-3 minutes then rinse well with water. Always use a fresh batch of bleach solution.

13.0 APPENDIX F: REINTRODUCTION GUIDELINES (HRPRG 1999)

These guidelines deal with the reintroduction of rare plants. Reintroduction should be a supplement to habitat management not a substitute. The final goal is not the success of an individual plant, but the establishment of a viable reproducing population where crosspollination can occur and in which genetic variation is maintained. An intermediate goal may be to establish a population for field stock or research reasons. It is expected that derivatives of the material in such field stocks will be outplanted more widely once appropriate habitat is secured and stabilized. These plants can be maintained as sources of seeds, cuttings or transplants for reintroduction efforts. Research activities may be intended to identify what factors are causing mortality/decline, to test methods to overcome these factors, or validate planting techniques. Ideally, successful research efforts will be permanent outplantings in their own right. Regardless of the intent of the planting, the process of reintroduction should consider the following guidelines. Many of the guidelines require coordination with other committees within the HRPRG as well as with agencies that may be collecting and propagating rare species. Included at the end of these guidelines is a list of contacts who may be contacted to consult on reintroductions. These guidelines have been broken into sections guiding actions prior, during, and following the actual transplanting of a plant.

Prior

Prior to the reintroduction of a plant, there are some issues that must be considered to ensure the health of the species, the individual transplanted plant and the surrounding habitat. This must include considerations of the reproductive biology of the species to be reintroduced.

Genetic Stock

The agency or individual that is reintroducing a plant must coordinate with the agencies or individuals responsible for the collection, and propagation of the plant. This must be done to ensure a healthy and balanced genetic composition. In addition a population geneticist may be consulted about strategies and alternatives when dealing with especially rare species or those with specific reproductive qualities. This is of course of special concern when dealing with depleted wild populations with remnant genetic stock. It should be the shared responsibility of all agencies and individuals involved to leave an easy-to-follow paper trail back to the source plant. (i.e. Rare Plant Monitoring Form, greenhouse accession numbers) Reintroduction is the last chance to make sure what we are propagating and planting represents a sufficient amount of the genetic composition of the species. Recalcitrant seed-producing plants may be taken as cuttings and helped into seeding in a greenhouse to increase the overall genetic base of the outplantings. Plants used in reintroduction should be as close to the collected field stock as possible. Plants that have been in the greenhouse for multiple generations may have been selected for different conditions than the reintroduction site and may have high attrition rates when planted. The pollination biology of each species must be researched and considered before reintroduction. Of special concern are pollen dispersal, autogamous (capable of self-pollination on a regular basis) and dioecious species, using propagules or plants from multiple year collections and mixing populations.

1. When reintroducing a species that is an outcrosser, one must consider the method of pollen dispersal. For example, wind pollinated species need to be planted close enough to ensure successful cross-pollination and species which require a pollinator must be planted in an area where an appropriate pollinator is known to exist. In a situation where one needs to keep a reintroduced population distinct from a wild population the site must be far enough to not allow cross-pollination. How far is enough is depends on the method of pollination (i.e. wind, insects, and birds).

2. One needs to determine if the species they intend to reintroduce is obligatively autogamous. Obligatively autogamous species tend to have genetically similar individuals due to their inability to outcross within a population. When collecting propagules for reintroducing an obligatively autogamous species, it is important to collect representatives from as many distinct populations as possible as opposed to getting representation from many individuals in one population as you would for an outcrossing species. If one intends to reintroduce an autogamous species it is important to maintain those distinct populations and not mix them when reintroducing. When reintroducing dioecious species one should plant equal numbers of male and female plants. If the plants are not yet mature and cannot be sexed, one should plant larger numbers of individuals to increase the effective population size.
3. When selecting the plants to be used in reintroduction, one must consider the age and year the stock was collected. Using propagules or plants from multiple years ensures better age class representation and possible genetic variety of stock.
4. Care should be taken not to mix gene pools that may be distinct and have local or microhabitat adaptations. A site with mixed stock should not be close to a population in which you seek to preserve representatives of geographically isolated subsets.

Maps

Prior to the reintroduction of a species, the area should be precisely mapped. Maps should include the historical and present range of the species, locations of known populations and proposed outplanting sites. A GIS database can also be used as a permanent record of the source of a particular population and to track the propagules. This will help ensure a genetic balance throughout the historical range.

Threat Abatement

Threats to a population should be noted on the Rare Plant Monitoring Forms used to monitor rare species. An entity involved with reintroduction must obtain copies of the Rare Plant Monitoring Forms to track the genetic composition of their plants. As always, consulting with anyone associated with the monitoring, collection and propagation of the species is necessary to get any other information. A management strategy addressing the threats compiled from the Monitoring Forms should be in place before plants are reintroduced. Strategies should include measures to control the most likely threats of ungulates and competition with non-native plants. Management activities must be conducted carefully as to not further degrade the habitat for reintroduction. All threat control techniques can be pathways for pathogens and other contaminants and must be executed properly. Weeding around an outplanting site may only proceed after careful considerations of the intent. Changing light regimes and soil composition can negatively impact the habitat for reintroduced plants. Also threats to a outplanted population may be different from those affecting the wild populations. For example, a wild population from which propagules are collected may be fenced and weeded but an ideal outplanting site existing off site within historical range may not have any management. Reintroduction should only proceed once a management strategy for the site has been established.

Site Selection

Once the historical range of the species is known and a management strategy is established, a suitable site for outplanting within the range must be selected. Again coordination with the collectors and propagators is essential. A site should be chosen according to the biotic and abiotic elements that comprise the habitat for the newly transplanted population. A careful review of the Rare Plant Monitoring Forms may provide all the information available on the source population. However, before outplanting, an agency or individuals should seek any additional information from anyone associated with the monitoring, collection, and propagation of the species. When interpreting historical range, one must consider that recent alterations of the habitats may have left the sites inhospitable for reintroduction. Invasion by alien species and other threats

may have left the habitat within historical range unsuitable due to changes in moisture regimes and soil composition. In such cases reintroduction may be most successful in sites outside known historical locations that have maintained the critical biotic and abiotic elements necessary for successful reintroduction.

Reintroduction scenario

Sites for reintroduction can be placed in at least three categories each having special considerations.

Reintroduction of a species within historical range

Agencies must consider what distinguishes populations from one another for each species that is to be outplanted. The site must be able to support a distinct population or one is only augmenting the adjacent population which may have different ramifications. Specific information about the habitat characteristics of the source population must be matched as close as possible with the outplanting site to provide the best chance for survival. This should be done by consulting anyone associated with the collection and propagation of the species and referring to the RPMFs.

Augmentations

This involves introducing propagules or plants into existing wild populations. This type of reintroduction must be considered on a case by case basis for each species. This reintroduction must be done carefully as to not harm the existing population with contaminants or physically altering the soil structure or existing roots. Augmentation may negatively alter the genetic composition of the population with propagules or plants from a single source or ones that have been raised through multiple generations in the greenhouse if not carried out strategically. Alternative scenarios are preferred due to the difficulty in ensuring a successful reintroduction. The complex problems involved with preventing pathogens from invading the wild population lowers the desirability of this option. It is especially important to contact as many individuals or agencies as possible for comments before augmenting a population.

Introduction of a species to a site outside the known historical range

Agencies or individuals considering this type of introduction need also to consider the possible negative effects on the species. Establishment of a healthy viable population may be hindered by loss of genetic variation being at a site away from other populations. Possible hybridization may occur when bringing a species outside its historical range and into the range of another related species. A site outside the known historical range may lack the habitat characteristics necessary for establishing a healthy population. Contrarily a site outside of the known historical range of the species may be the only place safe from the threats that brought the species to the remnant state we find them in today. In some cases, these sites may also offer the best management option for a particular species. It is also possible that the historical range is incomplete or no longer contain the most appropriate habitat including suitable moisture and soil composition.

Site Preparation

Once a proper site has been selected there are steps the agency or individuals can take to prepare it for reintroduction. In accordance with the management strategy for the species and site, it may be initially necessary to construct a small scale enclosure and/or weed nonnative competitors around the site. These actions should be taken in concurrence with protection of the greater habitat, which is critical to the success of an established population. The season in which to plant must be considered. Generally mesic and dry plant species would face less challenges if planted during a wet season. If drought conditions persist for more than a year, it may be beneficial to wait for a better year if storage conditions allow. Techniques for preparing the soil to receive and support a new plant differ depending on the species. One should consider digging holes in advance and composting material on site to provide a favorable substrate. Composting materials should come from on-site and ideally be from native material. Soils may also be tested to guide soil

preparation and future fertilization schemes. Coordination with the propagators is essential to ensure the fertilization and pesticide application schemes used in the greenhouse are adopted in the field. A catchment and watering system may also be considered.

During

The successful reintroduction from the greenhouse to the ground requires several issues to be taken into account.

Sanitation

Coordination with the propagator and collector is necessary to ensure that all aspects of rare plant handling is done with attention to sanitation. Collection should be done with sanitized tools and proper propagation techniques practiced to eliminate possible contaminants. Agencies and individuals involved with reintroduction need to coordinate with the propagator before the date of planting to make sure the propagules are prepared to go out. This may entail use of pesticides to ensure no foreign contaminants are transported to the site. The risk of spreading aliens via reintroduction activities must be adequately addressed and effectively eliminated. Seeds, slugs, disease, parasites, flatworms and other unintended inoculates must be prevented from being transported to the site by any aspect of the operation: protective management activities, materials, personnel and the plants themselves must all be completely free of contaminants. Care should be taken to clean all gear (boots, packs, planting tools, etc.) prior to arrival at the site to assure no contaminants are spread unknowingly.

Transport

Use caution when transporting fragile plants. Some species may need water or protection from the sun and wind during the transport. The most secure place in a vehicle for transporting plants is directly in back of the driver's seat.

Planting

Those involved in the planting of rare plants should be briefed before heading out to the site. Agencies and individuals directing reintroduction need to consider the techniques to be used in getting the plant from the container to the ground. Of special consideration is the decision to use a fertilizer in addition to any on site composting. In areas of low rainfall initial watering may be essential in easing the shock for the new plantings. Building up a pile of mulch around the base of a new plant can help to slow evaporation and keep water near the roots. A layer of cinder an inch thick placed around the base of a new planting can prevent slugs from reaching the plant.

Post

Following the reintroduction, monitoring is essential to maintain the health of the plant and the surrounding habitat.

Monitoring

Coordination with the agency or individual responsible for monitoring the existing populations may be necessary to see that a reintroduced population gets on a regular monitoring schedule. It is recommended that the site be monitored daily for a week after reintroduction. This close monitoring will insure that if there are problems with pests or other unforeseen threats such as drought, they can be addressed before they affect the plants. Use of the Rare Plant Monitoring Form (RPMF) will give important information pertaining to the location, phenology, population structure, habitat characteristics and threats to the new population. Individual plants may be labeled or tagged and tracked using the RPMF. The goal of a successful reintroduction is the establishment of a viable population that maintains the genetic variability of the species and produces successful offspring. Recruitment in the wild is necessary for the reintroduction to be deemed successful.

Monitoring a new population is essential to tracking the lineage of the population and to maintain local genotypes. A consistent monitoring schedule will also reduce the chance of a contaminant affecting the population or surrounding habitat. Recording the watering, fertilization and pesticide application schemes will help guide future reintroductions. CPC is currently working on a database to track safety net species including outplantings. Information on reintroduced populations should be transferred into the database.

Maintenance

Watering, fertilization and pesticide application may be necessary to ensure success. Supplemental watering especially in dry areas will greatly improve chances for a successful reintroduction.

Management

Actions after reintroduction must be taken in concurrence with a habitat management strategy. Reducing competition for resources with non-native plants by weeding may be necessary. A necessary ungulate exclosure may require maintenance.

List of Contacts

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14.0 APPENDIX G: DRAFT NORTH KONA WILDFIRE MANAGEMENT PLAN

14.1 Introduction

The Three Mountain Alliance (TMA) is a watershed partnership between Federal, State, and private landowners who wish to collaborate on land management issues affecting all of their lands. This group began as the ‘Ōla‘a Kīlauea Partnership, and after 10 years of success together they expanded their focus to include more of their lands that shared boundaries, values, and goals. This plan addresses wildland fire issues within the management area identified as North Kona. The North Kona Management Area (NKMA) landowners are Kamehameha Schools and the State of Hawai‘i. Although this landscape contains the interests of only two of the nine partners, they benefit from both the intellectual and physical resources available from all partners.

The purpose of this plan is to guide fire management programs that are responsive to TMA land management goals and objectives. The Three Mountain Alliance watershed partnership landowners share similar conservation goals and wish to coordinate their efforts across the landscape. One important rationale for creating such a large partnership, in respects to fire management, is that expensive resources can be shared between members.

The NKMA contains a large portion of lowland and montane dry forests and shrublands. Of all the TMA lands, this management area encompasses the largest area with the highest burn potential. This risk is coupled with the threat from invasive, fire-adapted grasses, which aggressively establish themselves following a wildland fire. Fountain grass is one such species which has increased its range by over 200% over a 40-year period. Due to the rough terrain and relative remoteness of much of the landscape, there are many intact remnant habitats that are threatened. Within State lands exists a small community posing a wildland urban interface hazard. Combining all of these issues highlights the importance of making fire protection a priority.

The wildland fire management plan discusses the characteristics of the landscape of the NKMA and its fire history. The plan describes all current fire assets, resources, and programs, and their current status. It also provides descriptions of the vegetation and fuel characteristics found on the landscape. Following a discussion of the current status of fire management, the plan will identify new prevention, pre-suppression, and suppression objectives, and provide cost estimates for their accomplishment.

The goal of the Three Mountain Alliance is to reduce the wildland fire occurrence and to minimize the impact wildland fires have on the ecosystem. The North Kona Management Area Wildland Fire Management Plan selects strategies towards accomplishing this goal.

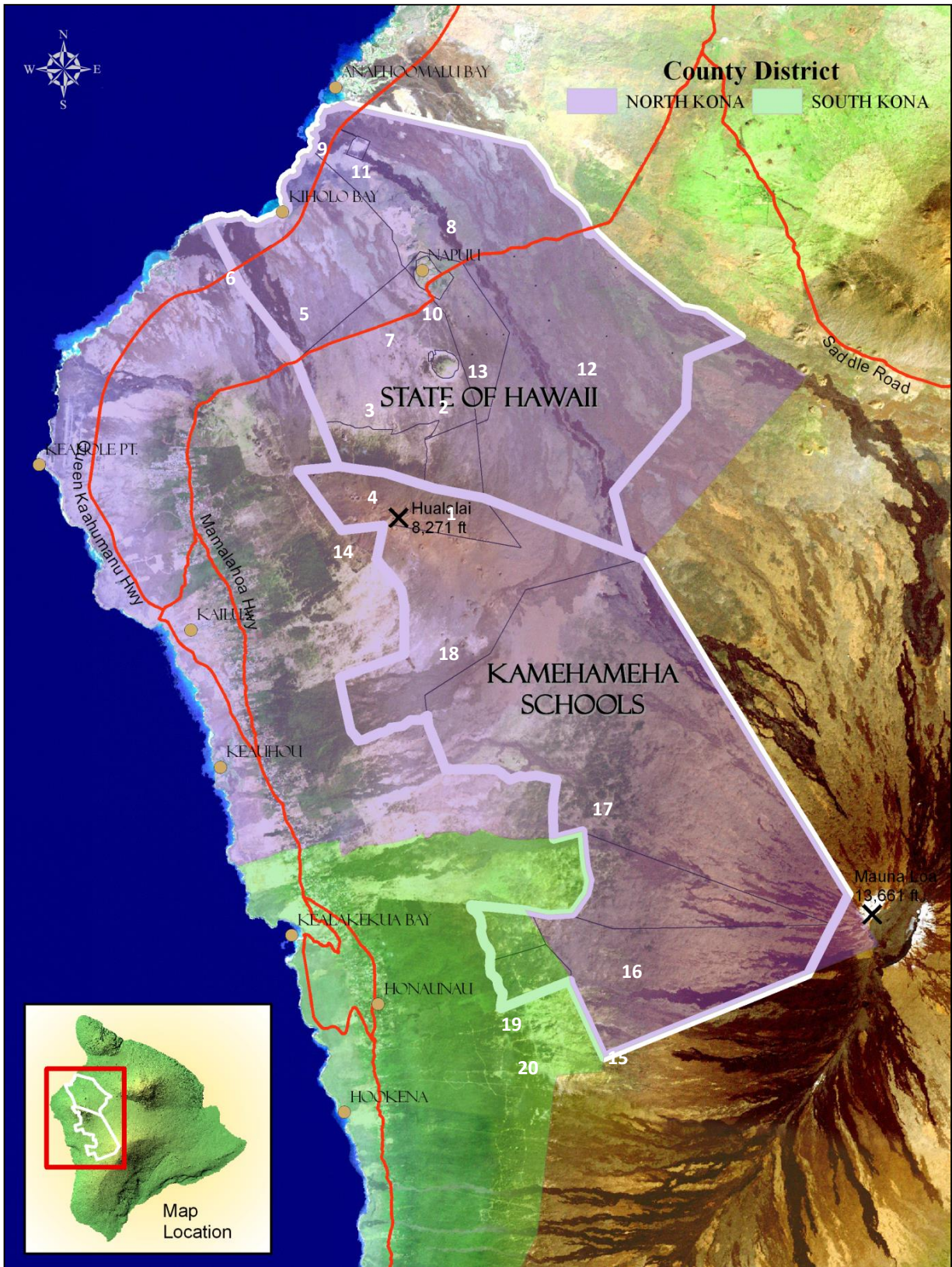


Figure 14.1 North Kona Management Area land ownership.

14.2 Land Management

The land area of concern within this plan is 237,110 acres²⁵. Of this, 98 % falls within the North Kona District jurisdiction of Hawai‘i County, and the remaining area (4,717 acres) is within the South Kona District. This tract, under the management guidance of the Three Mountain Alliance partners, is one of their four discrete management areas. The State of Hawai‘i and Kamehameha Schools are the two largest landowners which distinguish the land and its management. Although these two separate entities manage their lands by their precedence, the TMA has identified joint priorities on which to collaborate for resource management and research. The *Three Mountain Alliance Management Plan* (2007) summarizes the key threats which affect all partners’ lands and proposes management actions that they can pursue within each of their four management areas.

There are five current land uses within the North Kona Management Area: 1) ranching 2) hunting 3) native forest restoration 4) recreation and 5) forestry. The two landowners manage these uses differently; however it is the type of use, location, and intensity that is of concern to this plan.

14.2.1 Historic Land Management

Historical land use should be compared with the historical fire occurrences described in this document, so that inferences can be made about how and why fires occurred. It is beyond the scope of this plan to provide a detailed land use history. Prior to the earliest date listed it, would be correct to deduce that land uses were based around pre-contact Hawaiian culture.

The most significant change in land use occurred in the second half of the 19th century. The introduction of ungulates, e.g. cattle, sheep, and goats, and the use of forest land for grazing, began altering the vegetation composition. The first land leases for grazing occurred in 1865 in Pu‘u Anahulu of the Northern section, owned by the State, and 1873 in Keauhou II of the Southern section, owned by Kamehameha Schools. Following this alternative type of land use, new non-native species became naturalized during the 20th century, continuing to alter the landscape.

Families moved into the rural landscape as jobs were created to care for the livestock. During the 20th century, the community of Pu‘u Anahulu began to grow and was soon followed by a main highway (Hwy 190), the large residential community of Pu‘u Lani Ranch, and a golf course. The coast quickly developed, and in 1975 Queen Ka‘ahumanu Highway was finished, designating a second main thoroughfare. The mounting transformation in vegetation composition due to increasing anthropogenic changes, contributed to the prevalence of wildland fires. Humans soon became the number one cause of fires, surpassing lightning strikes.

14.2.2 General Land Management Policies

Current land use is regulated by State of Hawai‘i, Hawai‘i Administrative Rules (HAR) and Hawai‘i Revised Statutes (HRS). Under HRS Chapter 205 there are four approved land uses: 1) urban 2) rural 3) agricultural 4) conservation. The North Kona Management Area (NKMA) contains 93,329 acres in the agricultural district and 143,778 acres in the conservation district (Table 14.1). Additionally, the County of Hawai‘i designates its own zones on this land, yet bases them on control of housing density, and maintaining open space and forest cover.

Conservation districts are further divided into subzones, which are governed by Title 13, Chapter 5 of the HAR. The subzone designation limits the land use in order to protect the inherent conservation values found within a particular area. Most land uses are not allowed or highly regulated. For example, a wildfire fuels modification program may be implemented without permits or prior approval within agricultural land. However, if the same program was intended for conservation land, various procedures

²⁵ All acreages are calculated using ArcGIS software.

would need to be completed prior to implementation, based on the subzone classification. Figure 14.2 maps the governmental laws regulating the NKMA.

Table 14.1 NKMA Land Use District and Conservation subzone acreage.

Land Use	KS		State		Total	
	Area (ac)	Perimeter (mi)	Area (ac)	Perimeter (mi)	Area (ac)	Perimeter (mi)
Agriculture – total	49,999	65	43,331	49	93,329	114
Conservation - total	76,903	114	66,875	116	143,778	230
Conservation-General	0	0	13,965	39	13,965	39
Conservation-Resource	51,528	73	51,275	68	102,803	141
Conservation-Limited	14,855	22	1,635	9	16,491	31
Conservation-Protective	10,519	19	0	0	10,519	19

14.2.3 The Northern Section – State of Hawai‘i

The State of Hawai‘i owns the land on the Northern aspect of Hualālai within a region known as Kekaha (Figure 14.1). The ahupua‘a of Pu‘u Wa‘awa‘a and Pu‘u Anahulu contain this land area and are significant boundaries to the guidance and management of the area. In January, 2002, the management responsibility was transferred from the State of Hawai‘i Division of Land and Natural Resources-Land Division, to Division of Forestry and Wildlife, and Division of State Parks. This represented a significant land management change. It is notable that the land is further divided by management responsibility into three separate areas.

The first area is managed by the Department of Land and Natural Resources (DLNR), Division of Forestry and Wildlife (DOFAW). This area encompasses 103,987 acres. It begins at Queen Ka‘ahumanu Highway at an elevation of approximately 100 feet, and continues mauka (upslope) toward the summit of Hualālai, ending at approximately 6,400 feet. In Figure 14.1, these areas are identified as numbers 1-5, 7, 8, and 11-13. Within this area are the communities of Pu‘u Anahulu, Pu‘u Lani Ranch, and Big Island Country Club (see #10 on Figure 14.1). There are a total of twenty-one Tax Map Key (TMK) parcels, eleven of which are smaller than 1 acre and insignificant for planning purposes due to their small impact.

The area managed by DOFAW includes Pu‘u Wa‘awa‘a Forest Reserve (numbers 1-5 & 7 in Figure 14.1), so designated in October, 2007; Hawai‘i Experimental Tropical Forest (numbers 1-5 & 7 in Figure 14.1), established in March, 2007; Pu‘u Wa‘awa‘a Forest Bird Sanctuary (number 4 in Figure 14.1), set aside in May, 1998, and the Game Management Area of Pu‘u Anahulu (numbers 8, 12 & 13 in Figure 14.1), set aside in April, 1999.

In March, 2007 the DLNR and United States Department of Agriculture (USDA) Forest Service Institute of Pacific Islands Forestry established the Hawai‘i Experimental Tropical Forest (HETF). This experimental forest shares its boundary with the Pu‘u Wa‘awa‘a ahupua‘a, including the Pu‘u Wa‘awa‘a Forest Bird Sanctuary and Kīholo State Park. The purpose is to create opportunities where scientists and students can conduct research projects that will benefit management, preservation, conservation, and restoration. The projects implemented here will improve management and provide new knowledge which can be shared throughout the NKMA.

The second area is managed by the DLNR, Division of State Parks and encompasses 4,484 acres makai (downslope) of Queen Ka‘ahumanu Highway. This area is set aside as a State Park Reserve and includes such popular destinations as Kīholo Bay, Keawaiki Bay, Pueo Bay, and Weliweli (numbers 6 & 9 in Figure 14.1). There are a total of three parcels included in this area. This entire management area has received very little in the way of fire preparedness.

The third area has been transferred, by an executive order of the Governor, to the responsibility of the County of Hawai‘i. This 293-acre single parcel is managed as the West Hawai‘i Landfill. It is a “flag-lot” located mauka of Queen Ka‘ahumanu Highway (designated as number 11 in Figure 14.1). Because this area is located entirely on a lava flow there is no fire threat whatsoever.

When the State transferred land management responsibility in 2002 to DOFAW, a change in land use philosophy also occurred. The State of Hawai‘i intends, “to provide the basis and guidelines for managing Pu‘u Wa‘awa‘a and the makai lands of Pu‘u Anahulu in a manner that emulates the concept of ahupua‘a management” (State of Hawai‘i, 2003). Guiding principles of land management, i.e. goals and objectives, can be referenced in *The Management Plan for the ahupua‘a of Pu‘u Wa‘awa‘a and the Makai Lands of Pu‘u Anahulu* (2003). The state manages its land uses for restoration, forestry, hunting, and recreation under the DOFAW Management Guidelines which are all determined in part by the State land use district designation.

14.2.4 The Southern Section – Kamehameha Schools

Kamehameha Schools owns the Southern land, and refers to this area as Mauka Kona (Figure 14.1). It covers the area above the town of Keauhou starting at 3,400 feet, up the Southern aspect of Hualālai, and encompasses the summit at 8,271 feet. It also stretches to the South above the area of Hōnaunau, beginning in elevation at 4,300 feet and ascending near the summit of Mauna Loa at 12,900 feet. The total land area covered is 126,902 acres, which encompasses seven TMK parcels.

Land use across Kamehameha Schools (KS) is managed by their Land Assets Division (LAD) which adheres to their strategic plan written in 2003. The land use here is roughly segregated by TMK parcels.

Map ID 17 in Figure 14.2 contains land used for hunting, ranching, and conservation. Ranching use since the Greenwell’s departure in the 1980’s has not been intensive. There are between 50 and 200 head of cattle which graze around Pu‘u Lehua and below in an area named Koa Nui. Grazing occurs on only 10 % of the total area within the TMK.

Sheep hunting is the most intensive land use as assessed from the quantity of visitors. Concession hunts are run by allowing a licensee to hunt one to four days a week. Pig and goats are also hunted, though not as frequently as sheep. There are two cabins located on this parcel; Pu‘u Keanui cabin and Hale La‘au.

Native habitat restoration in this area has grown over the past decade and contains the largest area of māmane forest on the western slope of Mauna Loa. It is a possible site for pālila re-introductions, home to the largest remnant stands of ‘iliahi, and also home to several rare plants and insects. Restoration activities to date include invasive species control, ungulate management, and species monitoring. A 10,000 acre fence unit is schedule to be constructed in a few years through funding acquired by TMA.

Map ID 18 in Figure 14.2 has been leased to Palani Ranch since the 19th century. They use only a small portion for cattle pasture along the boundary of their fee simple land. However, unlike the Pulehua area, their operations are intensive. The rest of this parcel is unusable land covered in lava flows, and these areas are primarily used for hunting.

Map ID 16 in Figure 14.2 is licensed for sheep concession hunting and contains no infrastructure improvements. Recreational hunting here is typically one to three visits a week, by three to five persons.

Map ID 15, 19, and 20, in Figure 14.2, are also licensed for sheep hunting to an organized recreational group named Kahauloa Hunt Club, who only allow archery. The property’s contains two cabins one is the Kahauloa Hunt Club cabin, the other is a semi-improved structure at Gaspar’s Dairy.

Map ID 14 in Figure 14.2 contains the summit of Hualālai, Hainoa. This area is not encumbered and managed for conservation of the native habitat and restoration of degraded lands. Goats are not tolerated and sheep are well managed within this area. Hawaii Forest and Trail, an ecotourism company, provides

guided day trips to Ka‘ūpūlehu cinder cone on the Western end of the parcel. Hualālai is also a popular destination for hikers who wish to view the summit; although all hikers are considered trespassers.

There are two cabins on this parcel, Kipahe‘e and Duarte, located at 7,800 and 6,000 feet respectively. In addition to the cabins, there is one parcel owned by Hawai‘i Electric Company located at Ka‘ūpūlehu. This parcel contains various radio, television, and cell phone towers.

Kamehameha Schools’ mission is to provide high quality educational opportunities for Hawaiian children within their schools and on their land, as well. KS LAD recognizes the cultural and forest resources found within Mauka Kona and seek to provide for education, preservation, conservation, and economy. Throughout the year, high school student groups travel mauka for education, and graduates and post-graduates implement research, all of which feedback to KS, their constituents, and the scientific community.

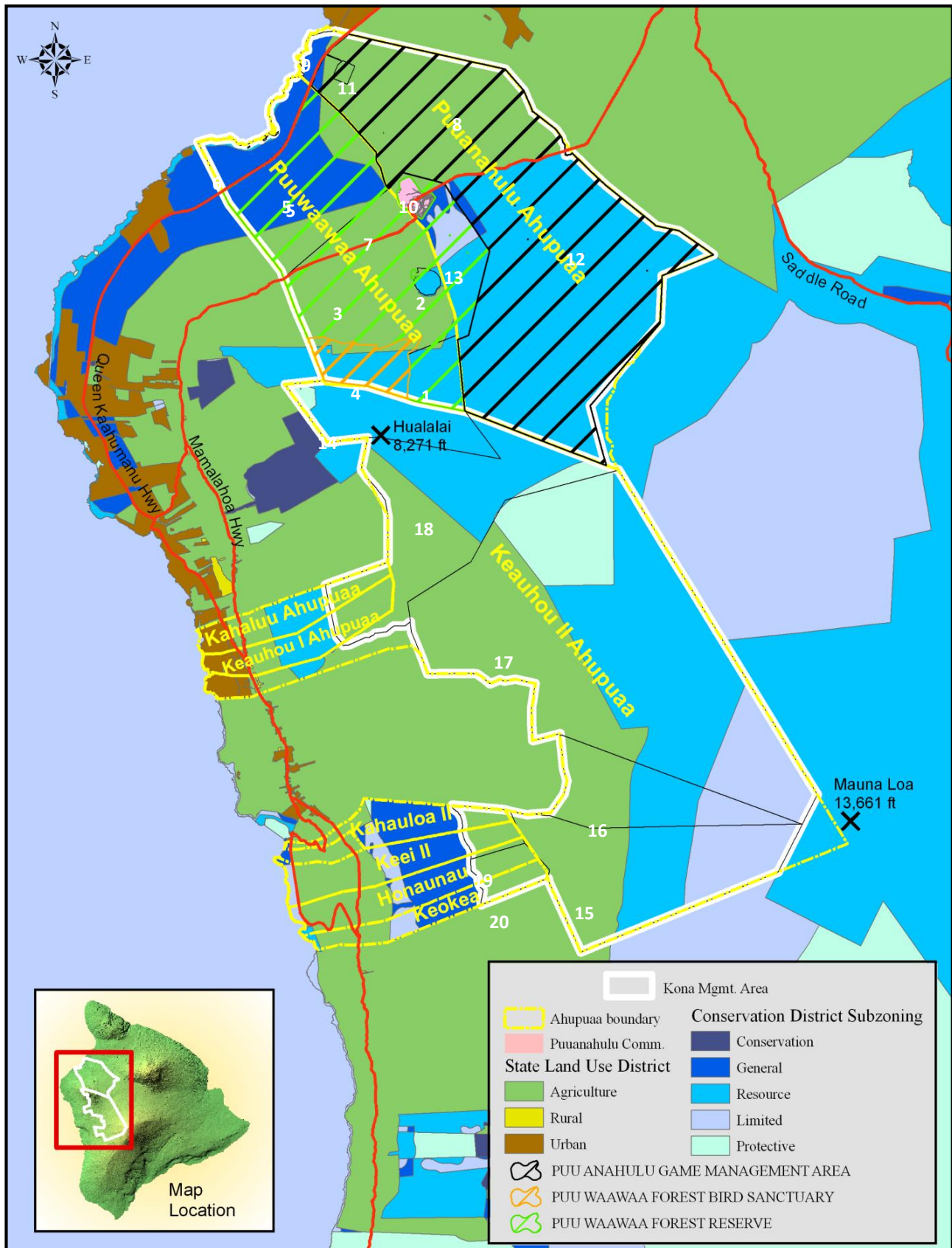


Figure 14.2 North Kona Management Area Government regulated land uses and Ahupua'a

14.2.5 Adjacent Land Ownership & Uses

Lands adjacent to the North Kona Management Area are owned by the State and Federal government, and large and small private landowners. The Kīholo State Park is bordered by the ocean, which provides unrestricted access to water.

Along the Northeast, East, and Southeast boundary, the land is owned by two departments of the Federal Government. Pohakuloa Military Training Area (PMTA) is owned by the Department of Defense and managed by the Army. On the East boundary is Volcanoes National Park managed by the Department of the Interior. Both of these neighbors manage their lands directly adjacent to NKMA for conservation and preservation, and are excellent neighbors in fire planning and preparedness.

Completely surrounded by State owned lands is the community of Pu‘u Anahulu, the largest rural development and the most densely populated area. Within this boundary, 409 acres is a golf course managed by the Big Island Country Club, 272 acres is a private gated-community named Pu‘u Lani Ranch, and 100 acres are various sized, privately owned lots (see Figure 14.3). Mamalahoa Highway is the only ingress and egress route for this community, which is cause for concern. Along the highway, and within the communities, are telephone and electric lines which are at risk to wildfire, as well. All homeowners are well educated to the risks from wildfire through the Firewise Communities program; however, their homes are still at risk to ignition from firebrands, radiation, and convection.

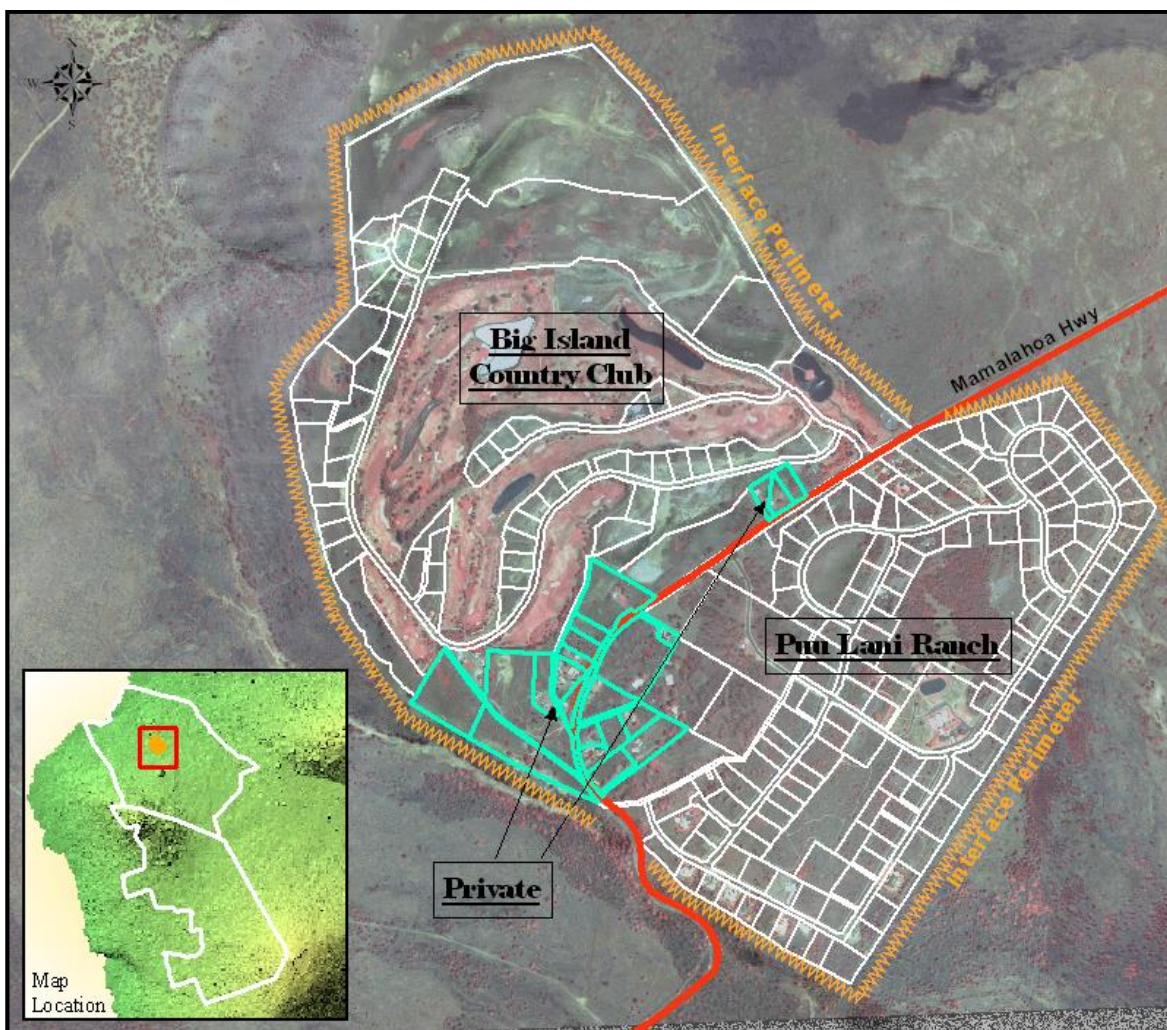


Figure 14.3 Community of Pu‘u Anahulu, Wildland Urban Interface (WUI).

On the makai side of Mamalahoa Highway, the interface between State land and the community is a perimeter of 2.7 miles, or 14,282 feet. The thirteen private home owners here are fortunate in being surrounded by a golf course which is an excellent fuel break. However, the golf course itself is at risk, because it is in the wildland interface. Mauka of Mamalahoa Highway, there is a much higher risk situation, because there are forty individual home owners directly on the wildland interface perimeter. This perimeter is 2 miles, or 10,500 feet, where fire breaks and defensible spaces need to be managed intensively.

There are fourteen privately owned parcels separate from the community, but still contained within State land (see Figure 14.4). There are eleven parcels makai of Queen Ka'ahumanu Highway bounded by lands managed by the Division of State Parks. The total privately held area along the coast is 44 acres, or less than 1% of the coastal land area. All of these aforementioned residences represent a Wildland Urban Interface (WUI).

The remaining three privately held parcels are within the Pu'u Wa'awa'a Ahupua'a and the Pu'u WaWa'awa'a Forest Reserve. One is owned by the Hawaii Electric Company, is insignificant in size at only a quarter acre, and has distinguished defensible space. However, due to the value and significance of the equipment (electric substation) within, it demands a high risk value. The other parcel is large, approximately 32 acres, and privately held. This property is a permanent residence and also has a high risk value. The last parcel is also within the same Ahupua'a, but within the Pu'u Wa'awa'a Forest Bird Sanctuary. It is privately held by the same owner as the 32-acre parcel, but is not a residence and only contains water catchment and storage space, and therefore it is of medium risk value.

Table 14.2 Pu'u Wa'awa'a Ahupua'a private land owners.

Parcel Owner	Acres	Defensible Perimeter (ft.)	Risk Value
Private	32.1	5,589	High
Private	2.8	1,400	Medium
Hawaii Electric Co.	.38	523	High

There are no small private residences directly adjacent to the NKMA lands owned by Kamehameha Schools in the Mauka Kona area. All of the land on the Southern border is agricultural land used for cattle ranching by the adjacent landowners. Cattle and sheep ranching have been a part of Mauka Kona for over a century, and there are four neighboring land owners still operating full-time, beef or cow-calf production, cattle ranches. Because their land is pasture, or grassland, it poses a high risk to wildfire because of the fine, flashy, grass fuels. Numerous fires are documented to have occurred in these pastures, and consequently pose wildfire threats to neighboring lands. A group like the Hawaii Wildfire Management Organization outreaching to assist these land owners in wildland fire planning would be highly beneficial.

Along the Western border there are also 2 Forest Reserves and open, unmanaged land (see Figure 14.5).

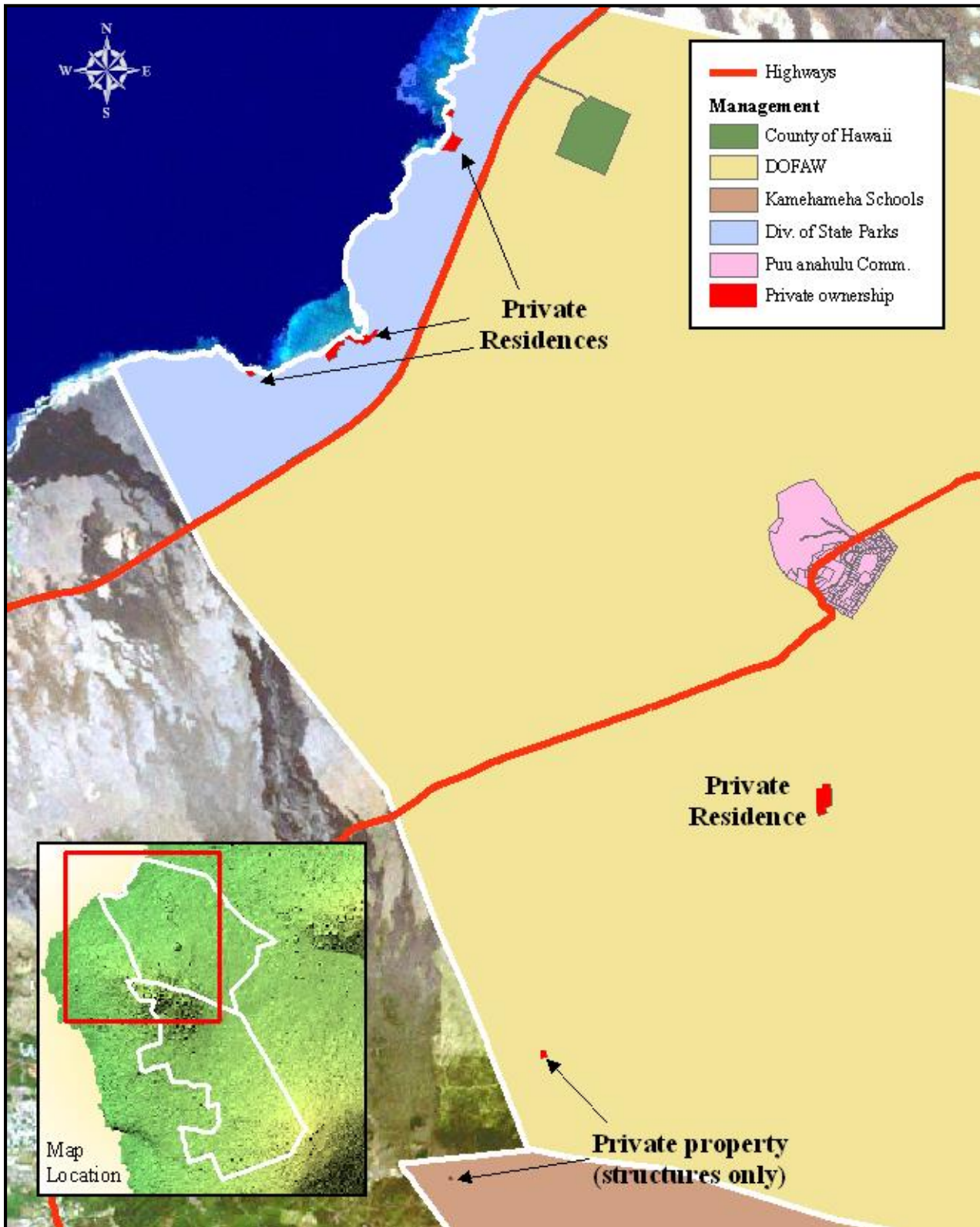


Figure 14.4 Miscellaneous parcels land locked within the NKMA.

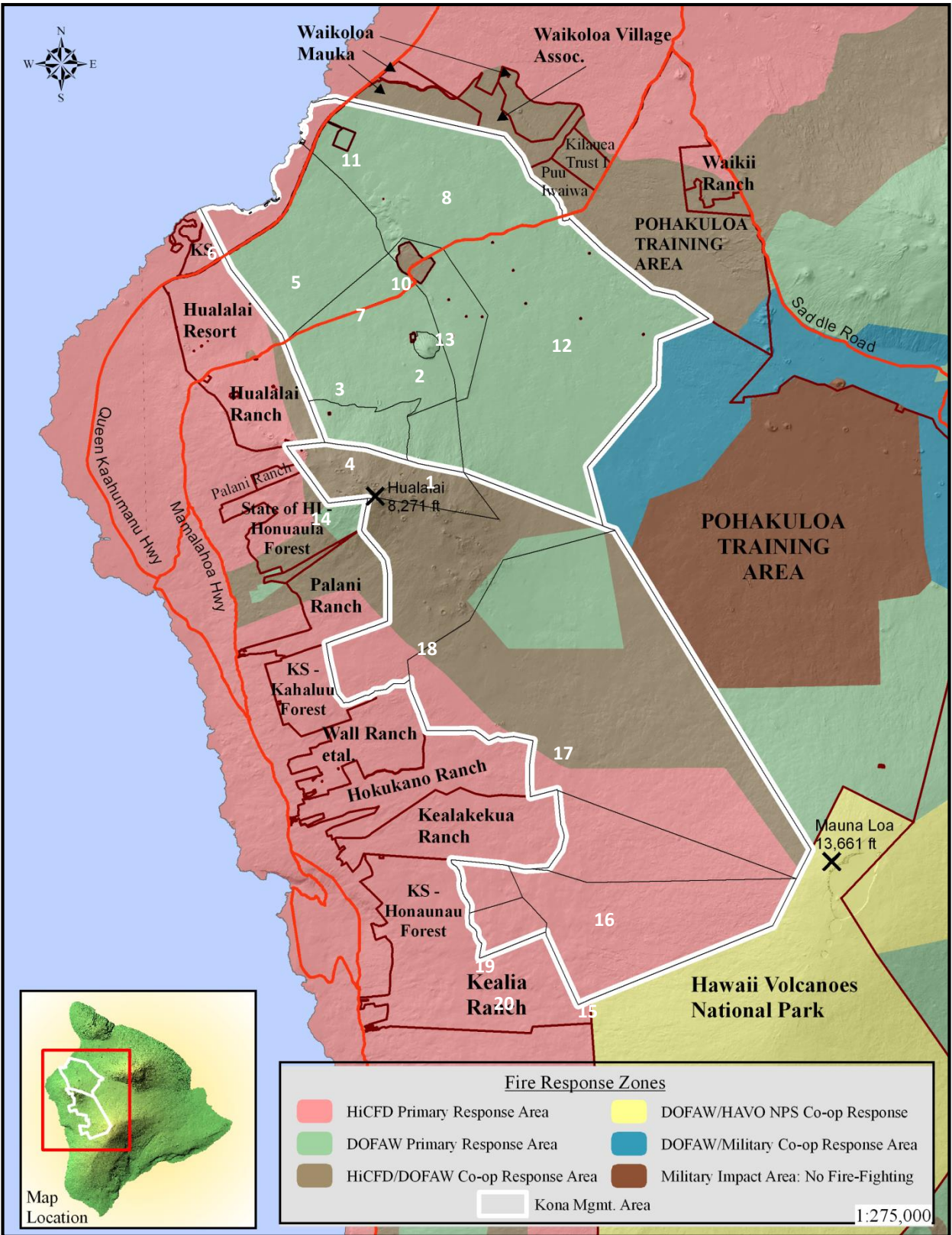


Figure 14.5 Fire agency wildland fire jurisdictions and large neighboring land owners

14.3 Wildland Fire Risk Assessment

The following sections assess the wildfire risks within the NKMA. They include the following: wildfire occurrence, fuel hazards, habitat, infrastructure, culture, recreation, aesthetic sites, economic, and other specified values found on the land. The consequences of a wildfire are that some, or all, of these values may be partially or completely lost. Priorities need to be identified for proper allocation of available financial and human resources. Identifying these priorities before a wildfire and taking action to mitigate the risks must occur in order to preserve a natural landscape.

14.3.1 Wildland Fire Occurrence (History)

Hawaiian ecosystems, although established on lava flows, have not evolved with wildfire. Fires were infrequent in the natural landscape; their usual source being lightning strikes. Only one community type has been documented to thrive under frequent fire occurrence from anthropogenic sources: pili (*Heteropogon contortus*) grassland. Some plants, however, are able to withstand quickly moving fires, and some germinate better following a fire. Since fire was not common, ecosystems did not adapt to be able to deal with the present, unnatural, human induced, fire return intervals.

There is ample evidence of recent fires throughout the NKMA. Additionally, there is verbal history and government documentation covering the last forty years. The Hawaii Wildfire Management Organization helped to develop the first fire history map for State lands within the NKMA in 2003. Similar mapping efforts have taken place on Kamehameha Schools land for the Mauka Kona area. These fire history maps are continuously being updated by DOFAW and HWMO. The value and data they provide are instrumental in understanding and planning for wildfire on the landscape. They also highlight the relative importance of unburned areas.

Under natural conditions, one would expect to see a fire return interval of 100 years or more in the NKMA, yet because of the conversion of some woodland to grassland, and a larger human population frequenting the area, the interval has decreased to 7-10 years in the Northern areas of NKMA. This has direct threats to the adjacent remnant native forests.

On KS lands, wildfires most frequently occur at Pulehua and Pu‘u Ika‘aka. These two areas have heavy human use due to cattle ranching and past logging. The dominant land cover type is non-native grassland, which has adapted to the grass-fire cycle. Fire history illustrates that fire return intervals have been longer when the ignition source is natural. However, during the 20th century, human presence was frequent, and so were wildfires. A recent decrease in human presence has resulted in a sporadic return of fire.

Other areas within Mauka Kona have had fires over the past thirty years, but most of these were small, infrequent, and caused by lightning strikes. A significant note is the absence of documented fires in areas above 6,000 feet.

14.3.2 Geography

Volcanoes, cinder cones, lava tubes, and lava flows make up the NKMA landscape. Each landform has unique geology, topography, and associated vegetation. While there are steep slopes, geophysical features play only a small role in wildfire behavior. Instead, fire behavior is more heavily determined by vegetation composition, substrate, and weather conditions during the fire.

There are two large active volcanoes, Hualālai and Mauna Loa that have moderate slopes rising to their summits. Hualālai most recently erupted in 1800 - 1801 creating the Huehue lava flow, which headed in a Northwest direction roughly along the Southwest border of Pu‘u Wa‘awa‘a ahupua‘a. The most recent eruption from Mauna Loa to influence the NKMA was in 1859 and runs along the Northern border of KS and PTA land, through Pu‘u Anahulu ahupua‘a, to the ocean. These two recent lava flows are sparsely vegetated which designates them as a natural fire break. However, fountain grass is slowly colonizing

these flows. There are other un-vegetated or sparsely-vegetated lava flows throughout the NKMA which also would not sustain wildfire and should be identified as firebreaks on suppression maps. Since the NKMA contains two active volcanoes, it should be recognized that a wildfire threat can also come from an eruption, however unpredictable this may be.

The second largest prominent feature is Pu‘u Anahulu ridge which extends makai from Pu‘u Wa‘awa‘a. This ridge was formed from a lava flow originating from Pu‘u Wa‘awa‘a and displays some of the steepest terrain covering a large area. The community of Pu‘u Anahulu sits at the top of this ridge and is at risk from a wildfire which may ignite here. A wildfire could quickly ascend the ridge, through fuel pre-heating, and threaten homes.

Cinder cones and volcanic vents are numerous and have the most topographic relief. They are characteristic of a steep hill protruding from the surrounding flat area. The largest of these is Pu‘u Wa‘awa‘a, and due to its age, soil development, and complex topography, supports greater botanical diversity than the surrounding area (Giffin, 2003). There are several more predominant features such as Pu‘u Lehua, Pu‘u O‘uo, Pu‘u Keanui, Kuainiho, and Po‘oho‘oho‘o and smaller vents and cinder cones that are scattered throughout the NKMA with similar diversity.

Another relevant feature, and a very hazardous one, is the lava tubes, caves, and cracks which are strewn throughout the NKMA. These are found predominantly on pahoehoe lava flows. Vegetation growing within them has been shown to carry underground fires. Not only are these features dangerous, they are filled with important cultural and biological resources.

Soils are volcanic, either a‘a, pahoehoe, cinder, or ash derived, and originate from either of the two aforementioned volcanoes. The age and composition, as well as depth, influence the vegetation community found thereon. One characteristic of younger cinder soils is their ability to carry a smoldering fire because of the relatively large particles of organic matter mixed into the surface layer. Many times these fires appear to be extinguished because there is no obvious smoking, and yet the fire is still burning. This is cause for concern during fire suppression.

14.3.3 Weather

Throughout the year, Kona is influenced by sea breezes during the day, bringing in moisture from the ocean, and moving it upslope. This is the convective-uplift rainfall effect, resulting from the land warming. At night, wind direction changes and cooler winds, land breezes, come from Mauna Loa and Hualālai toward the ocean. It is usually dry and hot, however, with afternoon rain and mist at elevations of 1,000 to 3,000 feet. Above 4,000 feet, an inversion layer often occurs, which precludes cloud movement. It also effectively blocks moisture, brought by the sea breezes, from traveling to higher elevations. Above this blanket of clouds, the temperature can be quite variable without the effects of thermo-regulation. Often, the only moisture comes in the form of fog drip, to high elevations. This effect can supply approximately 25% of the moisture between 4,000 and 8,000 feet. Lower relative humidity is experienced at the upper elevations above the inversion layer where moisture is typically absent.

The summer is typically the wet season, although it is the dry season for most of the state. However, in Kekaha, the wet season can shift to be in the spring or fall. Therefore, fire season across NKMA is usually between November and March, but observations of fire conditions and weather should preclude any seasonal predictions.

There are three storm events that also contribute to the annual rainfall. The first is a summer tropical storm, depression, or hurricane. These are infrequent and result in heavy flooding and high winds. Second, are two types of winter storms, reoccurring several times during the months of September through March. They bring a significant amount of moisture and also bring change in wind direction. A Kona storm brings in moist air from the South and light South to West winds, which create hazy conditions throughout the island. The other winter storm results from a passing cold front moving from east to west and dropping down from the North. This type of storm brings heavy rains and uncharacteristically cold, gusty winds. Both winter storms bring in a great deal of moisture, and raise the relative humidity, resulting in weather not as conducive to fire. However, the associated thunder and lightning still has the potential to light fires. Winter is the fire season; however, during this time there can be more rain from winter storms, than during the entire summer wet season.

Table 14.3 Temperature

Location	(°F)
Kīholo	76
Pu‘u Anahulu	68
PWWFBS Cabin	60
Hualālai	50
Hale La‘au	59
Pulehua	60
Ho‘olohe gate	64
Pu‘u O‘uo	50
Kahauloa cabin	59

Another unique attribute of NKMA is that it can be influenced heavily by global climate patterns, particularly El Niño. During an El Niño period it is possible to experience long periods of drought that could increase the risk of wildland fires within NKMA and prolong a fire season throughout the year.

A large Hawaiian knowledge base exists about the winds of these areas. Various wind names are related to particular places throughout the NKMA and each are described in ethnostudies. The wind is an important factor in wildfire behavior, and knowledge of the Hawaiian winds can be useful during all stages of fire planning.

Minimum annual temperatures start at 30° Fahrenheit near the summits of Hualālai and Mauna Loa during the winter months. Winter frost will occur during these months near the summits and has been documented as low as 5,500 feet. Maximum annual temperatures can reach 85° Fahrenheit. Average annual temperatures can be found to the right in Table 14.3.

Vog, the sulfur-based pollutant released from Kīlauea and other island volcanoes is blown back in towards leeward Hawai‘i because of the daytime sea breezes (‘Eka). The vog will not directly affect wildfires, but it will contribute to air pollution when smoke from a wildland fire is also considered. A combination of pollution factors creates very poor visibility and health risks to personnel and the public.

14.3.4 Vegetation, Fuels, and Resources

Fuel characteristics are diverse across NKMA, but are consistent within ecological regions and substrate types. The horizontal arrangement of these fuels is also varied, and where characteristics can be consistent in certain areas the continuity will remain diverse.

The largest concern is the displacement of native forests with invasive fire-promoting alien grass species. Within Pu‘u Wa‘awa‘a ahupua‘a, alien grasses increased by 237% between 1954 and 1994 (Blackmore and Vitousek, 2000). Although no similar studies have been made in the adjacent areas of Keauhou II and Pu‘u Anahulu ahupua‘a, a quick land cover analysis would result in finding an increased percentage in alien grass cover also. The four priority alien grass species are fountain grass (*Pennisetum setaceum*), kikuyu (*Pennisetum clandestinum*), buffel grass (*Cenchrus ciliaris*), and meadow rice grass (*Ehrharta stipoides*), they are all considered light or fine flashy fuels.

Hawai‘i Volcanoes (HAVO) National Park Fire Management Plan (2005) discusses in great detail the emerging fuel types and their characteristics. HAVO has the highest frequency of wildland fires in the

most habitat types, and this has allowed them to become the leader in wildland fire research. Fuel types found at HAVO are similar to ones found within NKMA; therefore they should be consulted for the latest research on wildland fire.

The NKMA comprises 9% of the island of Hawai‘i and within it exist some of the rarest and most valued biological, physical, and cultural resources. The resources found within Hawaii undergo continual stress from invasive threats, requiring anthropological mitigation for their survival.

Due to the degradation of these rare biological resources, one of the primary resource values being lost is the cultural and educational opportunities they provide to Hawaiians, Western science, and future generations. The island provided the necessary resources for Hawaiians, and still provides for the local community today. Off-shore and reef environments provided abundant marine fishery resources, inland agricultural zones used rich volcanic soils and ample rainfall to provide produce for island populations, and upland forested zones supplied materials used for canoes, house timbers, tools, and medicinal and ceremonial resources. These critical resources represent the essentials required to sustain island populations and were valued, protected, and preserved to ensure their sustainability (Three Mountain Alliance Management Plan, 2007). These uses and concepts are still relevant in modern society when recognizing the shifting reliance to local products and sustainability.

In the montane and lowland areas we find some of the largest ranges of high quality natural communities like grasslands and single species dominated forest, such as ‘iliahi and mamane. There also exist endangered birds, plants, and insects with restricted ranges. Sometimes these species are limited to their habitat, which can be as unique as lava tubes or caves like the ones commonly found throughout Pu‘u Wa‘awa‘a ahupua‘a. Toward the coastal areas, there are resources such as anchialine ponds, wetlands, and marine life also struggling to remain viable in spite of non-point pollution sources and invasive species. Along the coastal lands, there are many places where ground water enters the ocean providing life and health to coastal systems.

Of particular note is the resource of Hualālai and Pu‘u Wa‘awa‘a. These two physical features are old and complex, making them as unique and valuable as the life they sustain. The head waters for Waiaha stream reside on Kamehameha Schools land; the only true intermittent stream on the West side of the island. Throughout these areas, there are recreational uses such as hunting and hiking, and land used for agriculture. There are also cultural and historical resources distributed throughout the land, such as temporary residential sites, coastal and inland villages, ceremonial construction (*heiau*) and interment sites, trail networks, and boundary markers (Three Mountain Alliance Management Plan, 2007).

The NKMA is also a major watershed for the North and South Kona districts. The forested land here helps to catch and sustain the water which eventually recharges the aquifer; the main source of water in Kona. A diverse and complex landscape is needed for flood control, sediment filtration, and to mitigate the current effects of climate change.

The plant communities here epitomize sensitivity to wildfire. The native ecosystem and culture contained within, evolved with little impact from fire, which is why the current grass-fire cycle has been so destructive and will continue to be if left unabated. The following is a list of the ecoregions found within NKMA (see Figure 14.6 Eco-region Map).

1. Subalpine Dry Forest and Woodland
2. Subalpine Dry Shrubland
3. Subalpine Dry Grassland
4. Montane Dry Forest and Woodland
5. Montane Dry Shrubland
6. Montane Dry Grassland
7. Montane Mesic Forest and Woodland

8. Montane Mesic Grassland
9. Lowland Dry Forest and Woodland
10. Lowland Dry Shrubland
11. Lowland Dry Grassland
12. Coastal zone

Within Pu‘u Wa‘awa‘a ahupua‘a, 40 rare plants have been found, with 22 being listed as endangered or candidates (PWW Biological Assessment, 2003). The adjacent ahupua‘a of Pu‘u Anahulu has not been as extensively surveyed and no biological assessment exists for this area. A biological survey for Pu‘u Anahulu ahupua‘a is recommended. There are 4 endangered birds here: the nene (*Branta sandwicensis*), I‘o (*Buteo solitarius*), Hawai‘i ‘Akepa (*Loxops coccineus coccineus*), and Hawai‘i Creeper (*Oreomystis mana*). Also one endangered land mammal the ‘ope‘ape‘a (*Lasiurus cinereus semotus*). The US Fish and Wildlife Service should be consulted for an up-to-date list of the threatened, endangered, SOC, and sensitive species. Critical habitat plans can also be obtained from them for land planning.

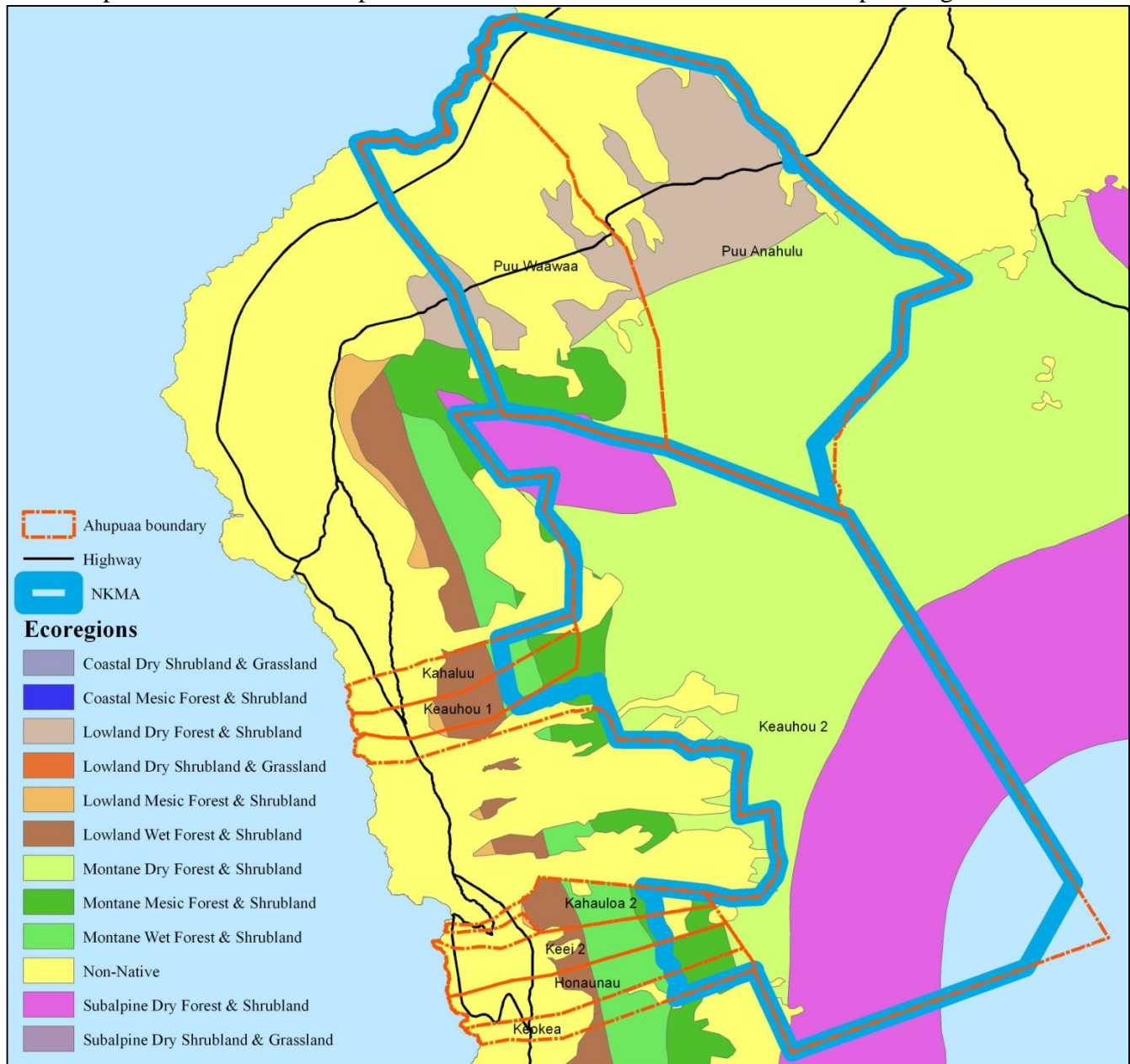


Figure 14.6 Ecoregions of the North Kona Management Area

14.3.5 Infrastructure

The infrastructure in this section reviews the risks of the resources managed within the NKMA. As mentioned previously, there are numerous parcels within the NKMA, but not managed by TMA, that are considered adjacent landowners. The majority of these properties are considered to be at high risk although there are suppression resources and defensible interfaces.

Structures

The majority of the structures within the NKMA are at high risk to wildfire. These structures include houses, cabins, sheds, water tanks, reservoirs, and utilities. Although the cost of losing any structure would be high, there are few high-valued structures that would need to be saved at all costs. These high-valued structures would include private homes and utilities.

The existing structures have not been fully assessed and documented as to their level of risk for wildfires. It is assumed that they are all highly ignitable and have minimal maintained defensible space around their perimeters. A GIS point layer database should be created to track information.

There are numerous water sources across NKMA. They are generally well distributed across KS land but, on State lands they are concentrated within the mauka portion of Pu‘u Wa‘awa‘a ahupa‘a. Most catchment tanks designated for wildfire use are reliable because their use is minimal for other operations. The capacity of the tanks ranges from a few hundred gallons to many thousand. Most tanks have been equipped for drawing water in the event of a fire. On State lands, many tanks have been linked together, which allows the movement of water from one area to another. This benefits the total water capacity of a particular area. Again, a GIS point layer database should be created to gather and track information concerning water tanks that can be readily available to managers.

Roads

Vehicle travel is slow and arduous, and requires appropriate vehicles. Currently maintained roads within the NKMA are designated in four classes: 1) highway 2) main 3) secondary and 4) spur. Each class has an associated travel speed and ID, identified within a GIS. Some roads have been given names, and this should continue. Some signs have been installed along these roads to help navigation. Within State lands, there are 407 acres that are highway right-of-ways and thirty-eight miles of highway frontage where wildlands are adjacent to heavily travelled highways. There are no public roads on KS land.

Utilities/Phone lines/Fence lines/Rock walls

There are no utility or phone lines across KS land except for one utility line partly up Kaloko Summit road going to the Kaloko communications towers. On State land within Pu‘u Wa‘awa‘a and Pu‘u Anahulu there is a utility line easement that parallels Queen Ka‘ahumanu Highway and Mamalahoa Highway.

Cell phone service is unreliable. However, some areas do receive signals for various service providers. Radio transmissions are also untrustworthy, and therefore reliable communications within working areas must be established during a fire event.

There are numerous fence lines throughout NKMA. Some have wood infrastructure and others have steel. Many are in disrepair and not in use anymore, however some are still used.

Rock walls also exist in the same conditions. Rock walls can be used as firebreaks if appropriately prepared before a fire. Unfortunately, no current map exists of the rock walls in NKMA.

There is a consistent lack of information documented on paper and in a GIS database regarding infrastructure. Creating and updating a GIS database should be a priority for TMA.

14.4 Wildland Fire Management Programs

14.4.1 General Management Considerations

Wildland fire management includes the consideration of three management concepts; prevention, pre-suppression, and suppression. Wildland fire prevention is conducted by the land owner in conjunction with other resource management goals and objectives. The TMA can assist with wildland fire prevention planning by coordinating the exchange of information and cooperatively raising funds to support common management objectives. Pre-suppression and suppression deal directly with wildland fires and is therefore a job for professional firefighters.

On Hawai‘i island, the Hawaii County Fire Department (HiCFD) responds initially to all wildland fires. They are the only full-time wildland fire-fighting agency that can respond to all calls (Hawaii Volcanoes National Park and Pohakuloa Military Training Area also keep full-time fire departments, but they are not initial responders). DOFAW, a State agency, is a wildland fire-fighting agency that is responsible for fire protection in Forest Reserves, public hunting areas, wildlife and plant sanctuaries, and Natural Area Reserves. DOFAW is better equipped than the HiCFD to fight fires in remote areas, and therefore shares fire-fighting responsibilities with them on a large portion of NKMA (see Figure 14.5).

There are several agencies on Hawai‘i island that fight fire; HiCFD, DOFAW, Hawaii Volcanoes National Park, US Army (Pohakuloa Military Training Area), and the US Fish and Wildlife Service. They have formed a group called the Big Island Wildfire Coordinating Group (BIGWICG) to organize mutual aid agreements, response, planning, and resources between the Federal and State agencies to improve wildland fire protection. These agencies, both collectively and independently, organize the pre-suppression and suppression of all wildland fires.

The state currently follows their *Operational Policy Handbook for Wildfire Control* for activities related to prevention, pre-suppression, and suppression of wildfires. Additionally, four operational objectives were outlined in the *Management Plan for the Ahupua‘a of Pu‘u Wa‘awa‘a and the Makai Lands of Pu‘u Anahulu* (2003) to help wildfire mitigation within these areas.

Prevention lays out programs for education, fire analysis, training, fuel modification (engineering), and law enforcement. The pre-suppression program includes training/certification, planning, preparedness, air operations, communications, and logistical services. Suppression refers to extinguishing wildfires, which is based on the guidelines in the National Wildfire Coordinating Group’s *Fireline Handbook*. The *Operational Policy Handbook for Wildfire Control* does not layout specific programs that occur on the landscape of DOFAW or Division of State Parks managed land.

In 2006, KS produced their first fire mitigation plan for the Mauka Kona area, meant to evaluate the wildfire risks, hazards, and suppression resources. This plan recommends actions to prepare KS in prevention, pre-suppression, and suppression. Each year, this plan is updated to include improvement in resources, fuel engineering projects, fire prevention, and employee training implemented during the prior year. One primary task when planning is to create Fire Management Units which differentiate blocks of land and their unique wildfire regimes. The creation of Fire Management Units (FMUs) should result from identifying areas with similar problems through wildfire occurrence mapping and land cover mapping. This information should then provoke discussions on wildland fire management strategies. Information should address the following for each FMU:

- Location
- Topography and elevation
- Climate
- Ecoregion
- Fuels and fire potential
- At risk T & E species (e.g. plants)
- Not at risk T & E species (e.g. birds)
- Infrastructure at risk
- Values at risk
- Fire season

- Fire history
- Suppression strategies
- Wildland fire use strategies
- Prescribed fire use strategies
- Non-fire fuel treatment programs
- Rehabilitation and restoration

Planning FMUs should be a top priority for land managers. This is a task that can be completed in cooperation with TMA, but should only be at the expense of the landowners' time to create a plan. No funding should be required.

14.5 Wildland Fire Prevention

The National Wildfire Coordinating Group defines prevention of wildfire as the, “activities directed at reducing the incidence of fires, including public education, law enforcement, personal contact, and reduction of fuel hazards (fuels management).” Planning for wildfire prevention includes reviewing all the aforementioned topics with decision makers for involved agencies and interested parties. Within the NKMA, this needs to take place between groups such as TMA, BIGWICG, DOFAW, State Parks, Kamehameha Schools, and communities.

14.5.1 Public Information and Education

Since humans are the number one cause of wildland fires in Hawai‘i, it is undeniable that the public needs to be continuously educated through outreach programs. Wildfire prevention education throughout the State occurs through the media and two National programs: Smokey the Bear and Firewise Communities.

A wildfire awareness brochure should be produced to hand out to those who wish to travel to NKMA. This can also be distributed along with additional wildfire education material at DOFAW offices in Waimea and Hilo. This brief handout should discuss fire prevention and what to do in case of a fire. It is usual for people to feel unthreatened by fire while in Hawai‘i because it is a wet tropical environment. However, in dryland forest areas wildfire is a serious threat of which visitors need to be aware. On the opposite side of this brochure could be a discussion about limiting the spreading of invasive species.

Fire condition public notices and area closure procedures should make aware the current fire conditions and resultant prohibited actions for NKMA. Public service announcements can make aware the fire conditions via newspaper, radio, and television. This is most applicable to the State-owned land in the North due to the large area of wildland-urban interface. All neighbors should be notified of conditions by a staff employee in order to promote positive relationships and partnering.

Fire condition notices through signage may not be enough to prevent a fire. During certain times of the year, when public use and fire potential is high, it may be justified to have a Fire Coordinator to patrol parking lots and roads to aid informing the public. This Fire Coordinator should work closely with the Protection Forester for the State.

The NKMA can be conceptually expanded to include all of the adjacent landowners. The wildfire hazards for neighboring landowners directly affect the NKMA. Yearly meetings or friendly phone calls to discuss and understand fire preparedness and mitigation measures will help to protect these lands. Areas of mutual aid for discussion should be water, access, fuels, and fire-fighting equipment.

14.5.2 Wildland Fire Occurrence

To prevent the occurrence of wildfires, we must look at their common causes, frequency, and where they occur. The frequency and location of wildfires within NKMA has been documented on GIS by the DOFAW, HWMO, and Forest Solutions. The database exists as the Fire History Maps for North and South Kona with the HWMO. This information can be utilized within the planning mechanism to provide feedback on other prevention, pre-suppression, and suppression activities.

The data collected on wildfires identifies the two primary causes of wildfires; anthropogenic and lightning. It also states that the human started wildfires are ignited 90% of the time along roadsides (PWW, 2003).

To show success in controlling wildfire occurrence, we must document a decrease in the fire return interval for wildfires within NKMA. This is best tracked through a GIS database on wildfires, which tracks the following: size, location, ignition source, date, burn length, suppression costs, % native burned, and % non-native burned. The current database should be updated to include this information. Cost for historical research and editing should not exceed \$15,000.

Task	Rate	Amount	Cost
Researcher	\$50/hr	160 hours	\$8,000
GIS analyst	\$50/hr	120 hours	\$6,000

A raster map showing fire frequency based on the number of wildfires occurring within any one cell can be created to show where wildfires are mathematically the most frequent. Updates to this GIS should not exceed \$2,500 annually.

14.5.3 Non-Fire Fuels Treatment Activities

Hazardous Fuel Reduction and Modification Recommendations

There are many natural resource management projects being conducted by the landowners of the NKMA which provide multiple benefits. For example, cattle-grazing provides both land lease fees and reduces grass fuels. Eradication of the non-native fountain grass improves native plant habitat and also reduces the fire threat due to a decrease in fine fuels. This style of project should be the focus when planning fuel reduction and modification objectives. It is more likely to receive funding for projects when the benefits are manifold, and even more so when there is an impact on human safety.

The following is a list of the current projects within NKMA:

1. 12 miles of fire breaks mauka and makai of Mamalahoa Highway within Pu‘u Wa‘awa‘a (State)
2. 12.2 miles of interior mowing to maintain fire breaks makai of Mamalahoa Highway Pu‘u Wa‘awa‘a (State)
3. Grazing management plan development by University of Hawaii College of Tropical Agriculture (State)
4. 3.6 mile new firebreak road Lupea and Mizotas Kīpuka (KS)
5. Fountain grass (*Pennisetum setaceum*) control program
 - a. Kīpuka Oweowe (24 ac) (State)
 - b. Reservoir paddock (43 ac) (State)
 - c. Mauka Kona (26,800ac) (KS)
6. Cattle grazing prescribed for fuel reduction at Pulehua (KS)
7. Cattle grazing prescribed for fuel reduction at Pu‘u Wa‘awa‘a (State)

Before any new projects are undertaken, maintenance and/or completion of existing projects should occur. The following list is proposed to work with existing projects, and also to help achieve landowner’s natural resource goals and fire prevention.

Project
Remove all non-native fine fuels between highway 190 and paddock boundary (rock wall or fence)
Location
Pu'u Wa'awa'a ahupua'a Hwy 190 firebreaks
Description
The total area of this project is estimated to be less than 75 acres, however the width of this area is quite varied as the fences and rockwalls meander in their distance from Hwy 190. The area is very accessible for control work and contains primarily non-native species. Once control is established within Pu'u Wa'awa'a ahupua'a after year 2, funds should be available to expand work to Pu'u Anahulu ahupua'a in a manner consistent with current fuels management projects.
Costs
Total cost year 1 = \$7,500 @ \$100/acre (cost includes labor and Roundup herbicide) Total cost year 2 = \$3,750 @ \$50/acre (cost includes labor and Roundup herbicide) Total maintenance cost year 3+ = \$2,250 @ \$30/acre (cost includes labor and Roundup herbicide) This work is estimated to take approximately 175 manhours

Project
Pu'u Anahulu biological assessment
Location
Ahupua'a of Pu'u Anahulu
Description
Design a biological assessment for the ahupua'a of Pu'u Anahulu that includes historical records and an in-field survey covering a minimum of 2% of the vegetated land area.
Costs
Costs will range dependent on who will complete the work. It is estimated to be between \$90 and \$140 per acre surveyed. Total project cost should not exceed \$150,000. The cost of a field survey can be minimized by evaluating the historical records within the area.

Project
Fountain grass compartmental control
Location
Pu‘u Wa‘awa‘a ahupua‘a
Description
Remove all fountain grass within fenced enclosures. Pu‘u Wa‘awa‘a ahupua‘a total 7,528 acres (fenced enclosures) & Keauhou II ahupua‘a total 10,000 acres (Lupea Habitat Management Area). Refine techniques with the goal of working towards control within select FMUs once they are designated.
Costs
Total cost year 1 = \$100/acre (cost includes labor and Roundup herbicide)
Total cost year 2 = \$50/acre (cost includes labor and Roundup herbicide)
Total maintenance cost year 3+ = \$30/acre (cost includes labor and Roundup herbicide)
A yearly budget should be obtained to do a consistent amount of acres while allowing for resweeping and maintenance of previously controlled acreage. It is feasible to replace Roundup with Imazapyr during the first year of control to extend control period and act as a pre-emergent. Roundup should be used in subsequent years.

Project
Pu‘u Lani Ranch WUI firebreak
Location
Mauka of Pu‘u Lani Ranch and at border of the Ranch and top of Pu‘u Anahulu ridge
Description
Remove all non-native fine fuels, ladder fuels, and thick brush between the community and state land – 10,500 ft distance at a minimum of 20 feet wide.
Costs
Brush clearance using a excavator with a large hydraulic masticating head @ \$450-605/acre
Fine fuels control at \$220/acre (cost includes initial weedwacker control followed with herbicide control one month later w/ Roundup). Total cost estimate \$8,500

Project
Defensible space construction around all existing structures and cultural sites
Location
Entire North Kona Management Area
Description
Defensible zones should be created around all existing structures according to Firewise Communities guidelines
Costs
The responsibility of this work should be taken by the land manager, ie DOFAW, State Parks, KS, and private parties. However, assistance should be offered by TMA and consultants and TMA managers should take the lead on following-up with this task.

14.5.4 Wildland Fire Law Enforcement

As stated earlier, humans are the primary cause of wildfires in Hawai‘i, and therefore authorities must make the public aware of the penalties that exist and follow through with prosecution. This should also be at the responsibility of the landowner on which the fire occurred. Fire law enforcement is carried out by the Division of Conservation and Resource Enforcement (DOCARE) under various laws (e.g. HRS Chapter 185, HAR 13.14-7, et al). Created public information signs should state that: “All violators may be prosecuted under HRS Ch. 185”, or something similar, to make them aware of the penalties for being irresponsible with fire in the open.

14.6 Wildland Fire Pre-Suppression

The National Wildfire Coordinating Group's definition of pre-suppression is: all activities in advance of fire occurrence to ensure effective suppression action. It includes planning the organization, recruiting and training, procuring of equipment and supplies, maintaining fire equipment and fire control improvements, and negotiating cooperative and/or mutual-aid agreements. Pre-suppression or preparedness actions are done by the agency in charge of suppression activities. On NKMA, this is the responsibility of HiCFD and DOFAW. The TMA and its partners, Kamehameha School, State Parks, and DOFAW, should still be responsible to work with these agencies via the BIGWICG to inform them of the resources on their land which can assist in wildland fire suppression. The following are a list of relevant issues:

- Land familiarity/Pre-attack planning
- Communications
- Knowledge of water resource
- Mapping (i.e. knowledge of roads, water sources, structures, species, fuels, topography, etc)
- Fire potential
- Hazards/Safety
- Training

The TMA can also coordinate funding to support the creation of more pre-suppression programs to help with the aforementioned.

- Training for private landowners could take place through grants and cooperation with Federal and State agency annual personnel training (e.g. Wildland Fire Behavior S-190).
- GIS data
 - Suppression assets and resources
 - Fuel potential/hazard
 - Fire/fuel breaks both natural and manmade
 - Fire suppression safety hazard mapping
 - Safety zone and staging area identification and mapping
 - Paddock map and waterlines in Pu'u Anahulu
 - Rock wall mapping
 - Cracks, caves, tubes, and other fire fighter hazards mapping
 - Infrastructure mapping of coastal resources: roads, structures, etc.
 - Utilities mapping
- Road naming and signage to aid navigation
- Fire weather (identifying past fire ignition with the historical weather records could yield valuable information)
- Mutual aid agreements –Mutual aid agreements for water and other resources should extend beyond the partners of TMA to the neighboring landowners as well. Because many adjacent land owners operate ranches there is potentially many things they can assist with including water, heavy machinery, tools, and man power.

14.6.1 Pre-Attack Planning of Suppression Equipment

Through the BIGWICG, it is recognized that the NPS, DOFAW, and PTA possess fire suppression equipment which is stored and maintained in their respective fire caches. A list of supplies and equipment is not currently available to the TMA, and would be relevant to scrutinize for possible improvements if one was attained. The partners within the TMA should make aware, and request assistance for, any

suppression equipment needs with which they can assist. TMA should prioritize and evaluate these requests for future funding.

Assisting with wildland fire suppression resources which are located in the field should be a priority objective for the TMA, i.e. water tanks, water lines, reservoirs, etc. The following are recommendations based on identifying wildland fire hazard areas; priority protection values and water resources. The map in figure 7 highlights areas in red which are more than three miles from a water source, have intact native forests with high biodiversity (an identified high value resource in the *Three Mountain Alliance Management Plan, 2007*), and are high fuel hazard areas.. Also highlighted on the map in green are areas that are more than three miles from a water source, have intact native forests with high biodiversity, but are not high fuel hazard areas.

Area 1 is 3,250 acres and located within an interface of lowland dry forest/shrubland and non-native grassland dominated by fountain grass. Area 2 is 31,900 acres and located in a very remote area dominated by montane dry forest and shrublands. A fire break, constructed by PTA, exists on the Eastern border of this area outside the NKMA. Area 3 is 39,000 acres and also very remote. This area is located within subalpine and alpine environments which have a very low burn potential because fuels are sparse.

The rest of the NKMA, outside of these “no water resource areas”, contains numerous water sources which can be utilized during suppression. The analysis also assumes that tankers can be provided along highway roadsides. Most water comes from rain catchment, which makes storage capacity an important pre-suppression planning item. Currently, there are 4 high priority projects for increasing water storage capacity within NKMA.

Recently completed water resource improvements and capacity building

1. Helicopter dip tank at Kīpuka Oweowe (State)
2. Waihou 1 new tank (State)
3. Pu‘u Wa ‘awa‘a Cone new tank (State)
4. Reline Pu‘u Wa‘awa‘a lake house reservoir (State)
5. 100 gallon mobile pump for initial attack (State)
6. Pa la‘au new tank 20,000 gallons (KS)
7. Pulehua new tank 20,000 gallons (KS)
8. Pulehua tank repairs, improve capacity by 20,000 gallons (KS)
9. Duarte Cabin new tank 4,000 gallons (KS)

Project
Hale Piula Water Catchment improvements
Description
Jim Juvik and Lori Tango wrote an excellent report on the Hale Piula catchment area and tanks in 2003. All of their analysis still applies, however the prices need to be updated. They state that the current effective catchment area is 77,000 sq. ft. providing 2.1 million gallons/yr. Improvements to Tank 1 catchment area should be followed by improvements to Tank 2 catchment area, which currently has a larger intact surface catchment area. This will provide an additional 4.9 million gallons per year, while minimizing improvements. Given the improvement in geosynthetics it is less cost effective and efficient to repair and/or install new bituminous pavement.
Tank 1 catchment area - line all bituminous paved surfaces with high density polyethylene (HDPE) Tank 2 catchment area – line all bituminous paved surfaces with HDPE which drain directly into Tank 2
Costs
Tank 1 - 95,000 sq.ft. @ \$0.995/sq.ft. ≈ \$94,500 includes geomembrane, liner, sandbags, clearing, and install Tank 2 – 90,250 sq.ft @ \$1.002/sq.ft ≈ \$90,500 includes geomembrane, liner, sandbags, clearing, and install

Project
Po‘oho‘oho‘o reservoir improvements
Description
Again, please reference the 2003 report of Juvik and Tango for specifics on the Po‘oho‘oho‘o reservoir. Reservoir 1 should be improved first followed by improvements to reservoir 2 if sufficient water is still not available. A key and cost effective component would be to connect Po‘oho‘oho‘o to hale piula via a 2 inch high density plastic pipe to collect excess water from this, the wettest area within the ahupua‘a.
Costs
Reservoir 1 – 86,000 @ \$0.997/sq.ft. ≈ \$85,750 includes geomembrane, liner, sandbags, clearing, & install Water transfer line – 10,100 ft @ \$1.00/ft ≈ \$xx,xxx includes installation Reservoir 2 – 165,000 @ \$1.001/sq.ft. ≈ \$165,155 includes geomembrane, liner, sandbags, clearing, & install

Project
Lupea Habitat Area water storage
Description
Annually increase water resource infrastructure within the protected area via water catchment and storage.
Costs
20,000 gallon corrugated steel tank ≈ \$4,500 484 sq.ft. elevated catchment roof ≈ \$9,500

Project
Hale La‘au water storage
Description
One time installation of a water resource near the Greenwell Hale La‘au Cabin
Costs
20,000 gallon corrugated steel tank ≈ \$4,500 484 sq.ft. elevated catchment roof ≈ \$9,500

14.6.2 Fire Weather/Fire Danger (NFDRS)

Fire season in Hawai‘i can be year round due to localized weather patterns creating dry conditions. Extended periods of drought and fire weather should be assessed with the National Fire Danger Rating System for Hawai‘i, also known as the Hawai‘i Fire Danger Rating System, operated on the Internet at <http://fireweb2a.pdc.org/ndfd/> by the Pacific Disaster Center. There are two Remote Automated Weather Stations (RAWS) located in Pu‘u Wa‘awa‘a ahupua‘a which collect real-time weather information. The National Oceanic and Atmospheric Administration (NOAA) also provides fire weather spot forecast upon request via their website at <http://www.prh.noaa.gov/hnl/pages/firewx.php>.

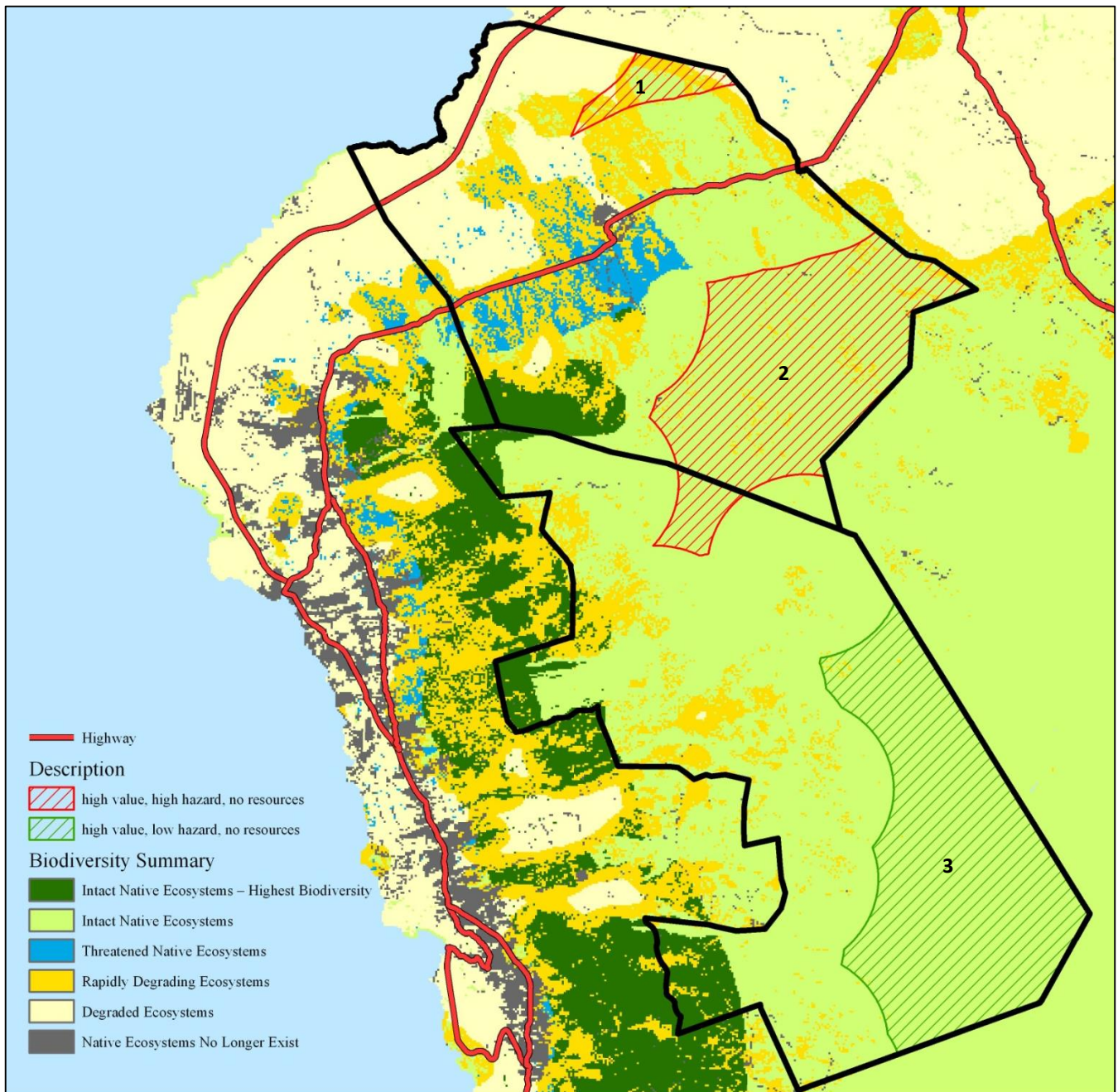


Figure 14.7 Map of identified “no water resource areas” in NKMA.

14.7 Wildland Fire Suppression (Emergency Operations)

14.7.1 Incident Management and Reporting

Fire suppression and initial attack are carried out by the County of Hawai'i Fire Department or the State Division of Forestry and Wildlife on all NKMA lands. KS does not keep or train fire-fighting personnel. Agency response is well organized by the various State and Federal agencies under BIGWICG. This group has developed a fire response zone map (FIGURE 14.5), which details areas of responsibility for various agencies. They also have comprehensive Memorandums of Understanding (MOU) when requesting help from partnering agencies for suppression assistance. All requests must go through the County of Hawai'i Civil Defense.

Upon responding to a wildland fire, all agencies utilize the Incident Command System (ICS) to manage all incidents. An Incident Commander will be immediately recognized on scene and should be assisted by a resource manager, i.e. Kamehameha Schools land manager, State Parks staff, etc. NWCG Publication 310-1 should be referenced regarding requirements and qualifications for wildland and prescribed fire personnel. The following information should be evaluated by the IC and Resource Manager during an initial attack:

- Fire Report
 - Fire name
 - Reporting party
 - Date/time fire was first observed and name of observer
 - Possible cause
 - Location
 - Access
 - Terrain and fuels
 - Size of fire
 - Visitors of personnel in the area
 - Anticipated problems
 - Threatened Values
 - Cause
 - Weather
 - Resources on fire
 - Resources needed
 - Fire behavior

- Public and firefighter safety
- Communities in the Wildland Urban Interface
- Cultural and historic resources
- Natural resources such as threatened and endangered species, sensitive and important habitat, vegetation maps
- Available suppression resources
- Fire behavior as determined by fuels, weather, and topography
- Natural and manmade fuel or fire breaks

Information and knowledge held by the TMA which could assist with wildland fire protection should be made readily available during a fire. The TMA coordinator should confirm communication between parties affected by the fire and offer support where necessary. If an initial attack does not contain the fire and/or continues to burn for longer than the initial operational consideration, an extended attack organization will be put into place under appropriate agency guidelines. At this point there is a federal resource called the Wildland Fire Decision Support System (WFDSS) which should be consulted by authorized personnel. Dependent upon the location of the fire, and the prevailing weather, there can be air quality hazards to the public. The IC should be aware of the air pollution being caused by the fire and work with the State Department of Health when necessary.

14.8 Wildland Fire Use

Naturally ignited wildland fire should be considered for use in accomplishing management goals. When FMUs are designated, a prescription should be assigned to utilize wildland fire, if one were to occur. Kamahameha Schools' land is not a candidate for this management regime (unless future research proves different), however lowland and coastal State-owned lands that may support a pili grass fire management regime or similar, should be evaluated.

14.9 Prescribed Fire

The use of prescribed fire as a management tool should be considered over the long-term using reliable research data. Prescribed fire can be used to reduce fuel hazards, manage ecological processes, remove invasive species, cycle nutrients, remove unwanted debris, as well as other management goals, however very little research exists on the subject in Hawai'i. One research experiment used prescribed fire, herbicide, and cattle grazing in Pu'u Anahulu to manage fountain grass fuel loads. They found out that the best prescription is a combination of all three management techniques (Castillo, 2009).

Prescribed fire does not have any applications in the near term for NKMA lands because it has not been utilized enough to be a reliable management tool and the risk of escape is high. However, prescribed fire research should be supported in order to develop its use as another tool. Slash pile and debris burns should be managed as prescribed fires.

14.10 Rehabilitation/Restoration

Following the suppression of a wildland fire two things should be evaluated within the burn area; areas needing rehabilitation and restoration back to a natural state. These two items should conclude a fire, and they are not part of a long-term restoration or monitoring project. Both can be mitigated through good planning and low impact suppression.

Rehabilitation work should return disturbed areas, like campsites and fire lines, back to a state that will promote native plant regeneration and discourage erosion, runoff, and invasive species. Bulldozed firebreaks are a vector for invasive weed infestations and illegal access. These firebreaks should be rehabilitated unless they are determined to be future roads or permanent fire breaks.

Post fire restoration plans should be created and implemented quickly to capitalize on the bare ground in front of invasive species. Equally important to re-vegetation is the control of undesired species through herbicide control. The wildland fire/invasive grass cycle can be broken through rapid, intensive restoration. Funds to accomplish this restoration work should be acquired and set aside each year.

14.11 Monitoring and Evaluation

Wildland fire and environmental monitoring should take place to collect background information that will assist in decision-making. There are numerous agencies willing to be part of a monitoring program and they can rapidly respond if plans are already in place. The Hawaii Tropical Experimental Forest is one such entity. Monitoring of weather, fuel conditions, vegetation, and fire observation can all contribute to better land management by TMA.

The implementation of post-burn monitoring through a program such as *Fire Effects Monitoring and Inventory System* should be evaluated as part of the pre-suppression planning program.

15.0 APPENDIX H: FUNDING MATRIX

The following pages contain three tables outlining the funding matrix for this HCP. Table 15.1 covers years 0-8 (Avoidance and Minimization), table 15.2 covers years 9-15 (Mitigation), and table 15.3 covers years 16-25 (Maintenance).

Table 15.1

<i>Ungulate Exclosures (contracting and materials)</i>	Quantity	Units	Unit Cost	Total Cost	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8
Henahena	3.3	miles	168,480.00	555,984.00	555,984.00							
Hala pepe	1.8	miles	168,480.00	304,748.57	304,748.57							
‘Aiea	3.0	miles	168,480.00	503,656.94		503,656.94						
Haplostachys	0.6	miles	168,480.00	97,360.42		97,360.42						
Solanum	0.8	miles	168,480.00	139,602.27		139,602.27						
Zanthoxylum II	4.6	miles	168,480.00	773,544.20			773,544.20					
Kauila Halapepe	3.4	miles	168,480.00	576,415.53			576,415.53					
Uhiuhi 4	0.8	miles	168,480.00	130,965.46			130,965.46					
Anahulu I	2.6	miles	168,480.00	441,471.90				441,471.90				
Anahulu II	2.2	miles	168,480.00	372,272.73				372,272.73				
Pu‘u Loa	4.2	miles	168,480.00	710,731.03					710,731.03			
Stenogyne	0.6	miles	168,480.00	93,801.00					93,801.00			
PWW CCA buffer	1.4	miles	168,480.00	230,210.27						230,210.27		
Mānele	1.8	miles	168,480.00	302,759.48							302,759.48	
Kohala	1.6	miles	168,480.00	262,140.30								262,140.30
Waihou II	2.3	miles	168,480.00	395,827.67								
Boundary Kipuka	1.2	miles	168,480.00	196,605.23								
Kileo	4.2	miles	168,480.00	709,300.80								
Lama Kokio	3.2	miles	168,480.00	544,171.44								
Fence checks and repairs for large exclosures	837.38	miles	558.00	507,814.30	2,850.72	5,303.62	10,208.40	12,903.49	15,568.07	16,330.52	17,333.25	18,201.45
Supplies for small spot fences	100	each	500.00	50,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00		
Labor		see full time labor crew										
Subtotal				7,899,383.55								
<i>Fire pre-suppression for ungulate exclosures and fuel breaks</i>	Quantity	Units	Unit Cost	Total Cost	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8
ATV with spray rig												
Annual Maintenance	2	each	500.00	25,000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
Truck spray rig	6	each	7,500.00	45,000.00								
Annual Maintenance	6	each	250.00	1,500.00								
Backpack sprayers	50	each	150.00	7,500.00	1500.00				1500.00			
Weed Whacker + PPE and supplies	42	each	750.00	31500.00	10500.00							10500.00
Herbicide + surfactant and dye	500	each	1,000.00	10,000,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00
Subtotal				10,140,500.00								

<i>Predator control</i>	Quantity	Units	Unit Cost	Total Cost	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8
Good nature A24 Rat Trap												
CO ₂ cartridge refills	250	10 pack	45.00	11,250.00	450.00	450.00	450.00	450.00	450.00	450.00	450.00	450.00
Rat lure replacement	250	10 pack	70.00	17,500.00	700.00	700.00	700.00	700.00	700.00	700.00	700.00	700.00
Rodenticide (for large conservation units)	?	?	?	?								
Subtotal				177,500.00								
<i>Ungulate control in ungulate exclosures</i>	Quantity	Units	Unit Cost	Total Cost	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8
Game drives (helicopter)												
Game traps	138	each	180.00	24,840.00	16,200.00	3600						
Ungulate monitoring		see full time crew										
GPS tracking collars	5	set	2,000.00	10,000.00	2,000.00				2,000.00			
Quarterly fence checks		see full time crew										
Subtotal				122,840.00								
<i>Mitigation and Net benefit</i>	Quantity	Units	Unit Cost	Total Cost	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8
Nursery Propagation (Volcano Rare Plant Facility) of covered species												
On-site Green House	1	each	6,500.00	6,500.00								
Green house maintenance and supplies	25	each	2,500.00	62,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00
Green House labor		See full time crew										
Common species propagation	150,000	each	6.00	900,000.00	36000.00	36000.00	36000.00	36000.00	36000.00	36000.00	36000.00	36000.00
Labor (seed collection and outplanting)		see full time field crew										
outplanting		see full time field crew										
pest control (ant/slug/aphid/etc)		acre	50.00	200,000.00								
Subtotal				1,251,000.00								
<i>Permanent Field Crew</i>	Quantity	Units	Unit Cost	Total Cost	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8
Project leader												
Crew Leader (including fringe)	1	each	59,000.00	1,475,000.00	59,000.00	59,000.00	59,000.00	59,000.00	59,000.00	59,000.00	59,000.00	59,000.00
Field Assistants (including fringe)	6	each	45,000.00	4,500,000.00	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00
Data management/nursery tech (including fringe)	1	each	45,000.00	1,125,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00
Volunteer Coordinator (including fringe)	1	each	45,000.00	1,125,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00
Vehicles for Crew	4	each	40,000.00	160,000.00	80000.00							
Annual maintenance	2	each	2,500.00	62,500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00
ATV	2	each	8,000.00	16,000.00	8,000.00							
2 Seater ATV	2	each	15,000.00	30,000.00	15,000.00							
Subtotal				10,118,500.00								

Monitoring	Quantity	Units	Unit Cost	Total Cost	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8
GPS units												
field supplies	25	annual	5,000.00	125,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00
Subtotal				132,000.00								
Blackburn's sphinx moth research												
Post-doc position plus supplies	3	each	100,000.00	300,000.00		100,000.00	100,000.00	100,000.00				
Subtotal				300,000.00								

<i>Ungulate Exclosures (contracting and materials)</i>	Quantity	Units	Unit Cost	Total Cost	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15
Henahena	3.3	miles	168,480.00	555,984.00							
Hala pepe	1.8	miles	168,480.00	304,748.57							
‘Aiea	3.0	miles	168,480.00	503,656.94							
Haplostachys	0.6	miles	168,480.00	97,360.42							
Solanum	0.8	miles	168,480.00	139,602.27							
Zanthoxylum II	4.6	miles	168,480.00	773,544.20							
Kauila Halapepe	3.4	miles	168,480.00	576,415.53							
Uhiuhi 4	0.8	miles	168,480.00	130,965.46							
Anahulu I	2.6	miles	168,480.00	441,471.90							
Anahulu II	2.2	miles	168,480.00	372,272.73							
Pu‘u Loa	4.2	miles	168,480.00	710,731.03							
Stenogyne	0.6	miles	168,480.00	93,801.00							
PWW CCA buffer	1.4	miles	168,480.00	230,210.27							
Mānele	1.8	miles	168,480.00	302,759.48							
Kohala	1.6	miles	168,480.00	262,140.30							
Waihou II	2.3	miles	168,480.00	395,827.67	395,827.67						
Boundary Kipuka	1.2	miles	168,480.00	196,605.23	196,605.23						
Kileo	4.2	miles	168,480.00	709,300.80		709,300.80					
Lama Kokio	3.2	miles	168,480.00	544,171.44		544,171.44					
Fence checks and repairs for large exclosures	837.38	miles	558.00	507,814.30	20,163.57	24,309.45	24,309.45	24,309.45	24,309.45	24,309.45	24,309.45
Supplies for small spot fences	100	each	500.00	50,000.00							
Labor		see full time labor crew									

Subtotal 7,899,383.55

<i>Fire pre-suppression for ungulate exclosures and fuel breaks</i>	Quantity	Units	Unit Cost	Total Cost	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15
ATV with spray rig	4	each	10,000.00	30,000.00				15,000.00			
Annual Maintenance	2	each	500.00	25,000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
Truck spray rig	6	each	7,500.00	45,000.00							
Annual Maintenance	6	each	250.00	1,500.00							
Backpack sprayers	50	each	150.00	7,500.00		1500					1500
Weed Whacker + PPE and supplies	42	each	750.00	31500.00							
Herbicide + surfactant and dye	500	each	1,000.00	10,000,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00

Subtotal 10,140,500.00

<i>Predator control</i>	Quantity	Units	Unit Cost	Total Cost	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15
Good nature A24 Rat Trap	250	5 Pack	595.00	148,750.00	5950.00	5950.00	5950.00	5950.00	5950.00	5950.00	5950.00

CO ₂ cartridge refills	250	10 pack	45.00	11,250.00	450.00	450.00	450.00	450.00	450.00	450.00	450.00	450.00
Rat lure replacement	250	10 pack	70.00	17,500.00	700.00	700.00	700.00	700.00	700.00	700.00	700.00	700.00
Rodenticide (for large conservation units)	?	?	?	?								

Subtotal **177,500.00**

<i>Ungulate control in ungulate exclosures</i>	Quantity	Units	Unit Cost	Total Cost	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15
Game drives (helicopter)	110	hours	800.00	88,000.00	16,000.00	8,000.00					
Game traps	138	each	180.00	24,840.00	3600						
Ungulate monitoring		see full time crew									
GPS tracking collars	5	set	2,000.00	10,000.00		2,000.00					2,000.00
Quarterly fence checks		see full time crew									

Subtotal **122,840.00**

<i>Mitigation and Net benefit</i>	Quantity	Units	Unit Cost	Total Cost	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15
Nursery Propagation (Volcano Rare Plant Facility) of covered species	10,250	each	8.00	82,000.00							
On-site Green House	1	each	6,500.00	6,500.00		6,500.00					
Green house maintenance and supplies	25	each	2,500.00	62,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00
Green House labor		See full time crew									
Common species propagation	150,000	each	6.00	900,000.00	36000.00	36000.00	36000.00	36000.00	36000.00	36000.00	36000.00
Labor (seed collection and outplanting)		see full time field crew									
outplanting		see full time field crew									
pest control (ant/slug/aphid/etc)		acre	50.00	200,000.00							

Subtotal **1,251,000.00**

<i>Permanent Field Crew</i>	Quantity	Units	Unit Cost	Total Cost	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15
Project leader	1	each	65,000.00	1,625,000.00	65,000.00	65,000.00	65,000.00	65,000.00	65,000.00	65,000.00	65,000.00
Crew Leader (including fringe)	1	each	59,000.00	1,475,000.00	59,000.00	59,000.00	59,000.00	59,000.00	59,000.00	59,000.00	59,000.00
Field Assistants (including fringe)	6	each	45,000.00	4,500,000.00	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00
Data management/nursery tech (including fringe)	1	each	45,000.00	1,125,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00
Volunteer Coordinator (including fringe)	1	each	45,000.00	1,125,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00
Vehicles for Crew	4	each	40,000.00	160,000.00				80,000			
Annual maintenance	2	each	2,500.00	62,500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00
ATV	2	each	8,000.00	16,000.00				8,000.00			
2 Seater ATV	2	each	15,000.00	30,000.00				15,000.00			

Subtotal **10,118,500.00**

Monitoring	Quantity	Units	Unit Cost	Total Cost	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15
GPS units	20	each	350.00	7,000.00		1400.00					1400.00
field supplies	25	annual	5,000.00	125,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00
Subtotal				132,000.00							
Blackburn's sphinx moth research	Quantity	Units	Unit Cost	Total Cost	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15
Post-doc position plus supplies	3	each	100,000.00	300,000.00							
Subtotal				300,000.00							

Item description														
<i>Ungulate Exclosures (contracting and materials)</i>	Quantity	Units	Unit Cost	Total Cost	YR 16	YR 17	YR 18	YR 19	YR 20	YR 21	YR 22	YR 23	YR 24	YR 25
Henahena	3.3	miles	168,480.00	555,984.00										
Hala pepe	1.8	miles	168,480.00	304,748.57										
‘Aiea	3.0	miles	168,480.00	503,656.94										
Haplostachys	0.6	miles	168,480.00	97,360.42										
Solanum	0.8	miles	168,480.00	139,602.27										
Zanthoxylum II	4.6	miles	168,480.00	773,544.20										
Kauila Halapepe	3.4	miles	168,480.00	576,415.53										
Uhiuhi 4	0.8	miles	168,480.00	130,965.46										
Anahulu I	2.6	miles	168,480.00	441,471.90										
Anahulu II	2.2	miles	168,480.00	372,272.73										
Pu‘u Loa	4.2	miles	168,480.00	710,731.03										
Stenogyne	0.6	miles	168,480.00	93,801.00										
PWW CCA buffer	1.4	miles	168,480.00	230,210.27										
Mānele	1.8	miles	168,480.00	302,759.48										
Kohala	1.6	miles	168,480.00	262,140.30										
Waihou II	2.3	miles	168,480.00	395,827.67										
Boundary Kipuka	1.2	miles	168,480.00	196,605.23										
Kileo	4.2	miles	168,480.00	709,300.80										
Lama Kokio	3.2	miles	168,480.00	544,171.44										
Fence checks and repairs for large exclosures	837.38	miles	558.00	507,814.30	24,309.45	24,309.45	24,309.45	24,309.45	24,309.45	24,309.45	24,309.45	24,309.45	24,309.45	24,309.45
Supplies for small spot fences	100	each	500.00	50,000.00										
Labor		see full time labor crew												
Subtotal				7,899,383.55										
<i>Fire pre-suppression for ungulate exclosures and fuel breaks</i>	Quantity	Units	Unit Cost	Total Cost	YR 16	YR 17	YR 18	YR 19	YR 20	YR 21	YR 22	YR 23	YR 24	YR 25
ATV with spray rig	4	each	10,000.00	30,000.00										
Annual Maintenance	2	each	500.00	25,000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
Truck spray rig	6	each	7,500.00	45,000.00										
Annual Maintenance	6	each	250.00	1,500.00										
Backpack sprayers	50	each	150.00	7,500.00					1500					
Weed Whacker + PPE and supplies	42	each	750.00	31500.00	10500.00									
Herbicide + surfactant and dye	500	each	1,000.00	10,000,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00
Subtotal				10,140,500.00										
<i>Predator control</i>	Quantity	Units	Unit Cost	Total Cost	YR 16	YR 17	YR 18	YR 19	YR 20	YR 21	YR 22	YR 23	YR 24	YR 25
Good nature A24 Rat Trap	250	5 Pack	595.00	148,750.00	5950.00	5950.00	5950.00	5950.00	5950.00	5950.00	5950.00	5950.00	5950.00	5950.00

Item description														
CO ₂ cartridge refills	250	10 pack	45.00	11,250.00	450.00	450.00	450.00	450.00	450.00	450.00	450.00	450.00	450.00	450.00
Rat lure replacement	250	10 pack	70.00	17,500.00	700.00	700.00	700.00	700.00	700.00	700.00	700.00	700.00	700.00	700.00
Rodenticide (for large conservation units)	?	?	?	?										
Subtotal				177,500.00										
Ungulate control in ungulate exclosures	Quantity	Units	Unit Cost	Total Cost	YR 16	YR 17	YR 18	YR 19	YR 20	YR 21	YR 22	YR 23	YR 24	YR 25
Game drives (helicopter)	110	hours	800.00	88,000.00										
Game traps	138	each	180.00	24,840.00										
Ungulate monitoring		see full time crew												
GPS tracking collars	5	set	2,000.00	10,000.00					2,000.00					
Quarterly fence checks		see full time crew												
Subtotal				122,840.00										
Mitigation and Net benefit	Quantity	Units	Unit Cost	Total Cost	YR 16	YR 17	YR 18	YR 19	YR 20	YR 21	YR 22	YR 23	YR 24	YR 25
Nursery Propagation (Volcano Rare Plant Facility) of covered species	10,250	each	8.00	82,000.00										
On-site Green House	1	each	6,500.00	6,500.00										
Green house maintenance and supplies	25	each	2,500.00	62,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00
Green House labor		See full time crew												
Common species propagation	150,000	each	6.00	900,000.00	36000.00	36000.00	36000.00	36000.00	36000.00	36000.00	36000.00	36000.00	36000.00	36000.00
Labor (seed collection and outplanting)		see full time field crew												
outplanting		see full time field crew												
pest control (ant/slug/aphid/etc)		acre	50.00	200,000.00										
Subtotal				1,251,000.00										
Permanent Field Crew	Quantity	Units	Unit Cost	Total Cost	YR 16	YR 17	YR 18	YR 19	YR 20	YR 21	YR 22	YR 23	YR 24	YR 25
Project leader	1	each	65,000.00	1,625,000.00	65,000.00	65,000.00	65,000.00	65,000.00	65,000.00	65,000.00	65,000.00	65,000.00	65,000.00	65,000.00
Crew Leader (including fringe)	1	each	59,000.00	1,475,000.00	59,000.00	59,000.00	59,000.00	59,000.00	59,000.00	59,000.00	59,000.00	59,000.00	59,000.00	59,000.00
Field Assistants (including fringe)	6	each	45,000.00	4,500,000.00	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00
Data management/nursery tech (including fringe)	1	each	45,000.00	1,125,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00
Volunteer Coordinator (including fringe)	1	each	45,000.00	1,125,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00	45,000.00
Vehicles for Crew	4	each	40,000.00	160,000.00										
Annual maintenance	2	each	2,500.00	62,500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00
ATV	2	each	8,000.00	16,000.00										
2 Seater ATV	2	each	15,000.00	30,000.00										
Subtotal				10,118,500.00										
Monitoring	Quantity	Units	Unit Cost	Total Cost	YR 16	YR 17	YR 18	YR 19	YR 20	YR 21	YR 22	YR 23	YR 24	YR 25

Item description															
GPS units	20	each	350.00	7,000.00					1400.00						
field supplies	25	annual	5,000.00	125,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	
Subtotal				132,000.00											
<i>Blackburn's sphinx moth research</i>		Quantity	Units	Unit Cost	Total Cost	YR 16	YR 17	YR 18	YR 19	YR 20	YR 21	YR 22	YR 23	YR 24	YR 25
Post-doc position plus supplies	3	each	100,000.00	300,000.00											
Subtotal				300,000.00											
TOTAL:				30,141,723.55											

16.0 LITERATURE CITED

- Allen, W. 2000. Restoring Hawai'i's dry forests. *BioScience* 50:1037-1041.
- Army, U. S. 2003a. Appendix 1.2 Reintroduction Guidelines Hawai'i Rare Plant Restoration Group. Implementation Plan Makua Military Reservation, Island of Oahu. Wil Chee-Planning Inc., Honolulu, HI.
- Army, U. S. 2003b. Implementation Plan Makua Military Reservation, Island of Oahu. United States Army Garrison, Hawaii, Directorate of Public Works Environmental Division. Wil Chee-Planning Inc., Honolulu, HI.
- Army, U. S. 2010. Implementation Plan Pōhakuloa Training Area Island of Hawai'i. Directorate of Public Work, Environmental Division. Pōhakuloa Natural Resource Office. Hilo, Hawai'i.
- Arnett, M. 2002. Report of Survey for Rare Plants on the Keamuku Parcel, Island of Hawai'i. Center for Environmental Management of Military Lands, Colorado State University, Fort Collins, CO.
- Athens, J. S., H. D. Tuggle, J. V. Ward, and D. J. Welch. 2002. Avifaunal extinctions, vegetation change, and Polynesian impacts in prehistoric Hawai'i. *Archaeology in Oceania* 37:57-78.
- Black, J. M., J. Prop, J. M. Hunter, F. Woog, A. P. Marshall, and J. M. Bowler. 1994. Foraging behavior and energetics of the hawaiian goose *Branta sandvicensis*. *Wildfowl* 45:65-109.
- Blackmore, M., and P. M. Vitousek. 2000. Cattle grazing, forest loss, and fuel loading in a dry forest ecosystem at Pu'u Wa'awa'a Ranch, Hawai'i. *Biotropica* 32:625-632.
- Brooks, S., S. Cordell, and L. Perry. 2009. Broadcast seeding as a potential tool to reestablish native species in degraded dry forest ecosystems in Hawaii. *Ecological Restoration* 27:300-305.
- Bruegmann, M. M. 1996. Hawai'i's dry forests. *Endangered Species Bulletin* 11:26-27.
- Bullock, S., H. A. Mooney, and E. Medina. 1995. *Seasonally Dry Tropical Forests*. Cambridge University Press, Cambridge, MA.
- Burney, D. A., H. F. James, L. P. Burney, S. L. Olson, W. Kikuchi, W. L. Wagner, M. Burney, D. McCloskey, D. Kikuchi, F. V. Grady, R. Gage II, and R. Nishek. 2001. Fossil evidence for a diverse biota from Kaua'i and its transformation since human arrival. *Ecological Monographs* 71:615-641.
- Cabin, R. J., S. G. Weller, D. H. Lorence, S. Cordell, L. J. Hadway, R. Montgomery, D. Goo, and A. Urakami. 2002. Effects of light, alien grass, and native species additions on Hawaiian dry forest restoration. *Ecological Applications* 12:1595-1610.
- Cabin, R. J., S. G. Weller, D. H. Lorence, T. W. Flynn, A. K. Sakai, D. Sandquist, and L. J. Hadway. 2000. Effects of Long-Term Ungulate Exclusion and Recent Alien Species Control on the Preservation and Restoration of a Hawaiian Tropical Dry Forest. *Conservation Biology* 14:439-453.
- Campbell, T. A., and D. B. Long. 2009. Feral swine damage and damage management in forested ecosystems. *Forest Ecology and Management* 257:2319-2326.
- Carlquist, S. 1980. *Hawai'i: a natural history*. National Tropical Botanical Garden, Lawai, Hawai'i.
- Castillo, M. J., G. Enriques, M. Nakahara, D. Weise, L. Ford, R. Moraga, and R. Vihnanek. 2007. Effects of cattle grazing, glyphosate, and prescribed burning on fountaingrass fuel

- loading in Hawai'i. Pages 230-239 in R. E. Masters and K. E. M. Galley, editors. Proceedings of the 23rd Tall Timbers Fire Ecology Conference: Fire in Grassland and Shrubland Ecosystems. Tall Timbers Research Station, Tallahassee, Florida.
- CCSP. 2009. Our Changing Planet. U.S Climate Change Science Program.
- Clague, D. A., and G. B. Dalrymple. 1987. The Hawaiian-Emperor Volcanic Chain, Part 1, Geologic Evolution. Pages 5-54 in R. W. Decker, T. L. Wright, and P. H. Stauffer, editors. Volcanism in Hawai'i. U.S. Geological Survey Professional Paper 1350. U.S. Government Printing Office, Washington, D.C.
- Coblentz, B. E. 1978. The effects of feral goats (*Capra hircus*) on island ecosystems. *Biological Conservation* 13:279-286.
- Cole, R. J., C. M. Litton, M. J. Koontz, and R. K. Loh. 2012. Vegetation recovery 16 years after feral pig removal from a wet Hawaiian forest. *Biotropica* 44:463-471.
- Cordell, S., and D. R. Sandquist. 2008. The impact of an invasive African bunchgrass (*Pennisetum setaceum*) on water availability and productivity of canopy trees within a tropical dry forest in Hawaii. *Functional Ecology* 22:1008-1017.
- Cuddihy, L. W., and C. P. Stone. 1990. Alteration of native Hawaiian vegetation. Cooperative National Park Resources Studies Unit, University of Hawai'i, Honolulu.
- D'Antonio, C. M., F. Hughes, and T. Tunison. 2011. Long-term impacts of invasive grasses and subsequent fire in seasonally dry Hawaiian woodlands. *Ecological Applications* 21:1617-1628.
- D'Antonio, C. M., and P. M. Vitousek. 1992. Biological invasions by exotic grasses, the grass-fire cycle, and global change. *Annual Review of Ecology and Systematics* 23:63-87.
- Diong, C. H. 1982. Population biology and management of the feral pig (*Sus scrofa* L.) in Kipahulu Valley, Maui. PhD thesis, University of Hawaii, Honolulu.
- DLNR. 2003. Management plan for the ahupua'a of Pu'u Wa'awa'a and the makai lands of Pu'u Anahulu. Department of Land and Natural Resources, Division of Forestry and Wildlife.
- DLNR. 2007. Review of Methods and Approach for Control of Non-native Ungulates in Hawai'i. Department of Land and Natural Resources, Division of Forestry and Wildlife No. 07-01.
- Ekem, P. C., and J. H. Chang. 1985. Pan Evaporation: State of Hawai'i, 1894–1983. Department of Land and Natural Resources, Division of Water and Land Development.
- Elmore, A. J., and G. P. Asner. 2006. Effects of grazing intensity on soil carbon stocks following deforestation of a Hawaiian dry tropical forest. *Global Change Biology* 12:1761-1772.
- Environment. 2015. Of Earthworms and Pigs Environment Hawai'i 26.
- Fletcher, C. H. 2009. Sea level by the end of the 21 century: A review. *Shore and Beach* 77.
- Fujii, J. 1995. In the Lee of Hualalai: Historic Kaupulehu. First edition. Kaupulehu Makai Venture, Kailua-Kona, HI.
- Fukunaga. 2010. Final Report: Hawai'i County Water Use and Development Plan Update County of Hawai'i Department of Water Supply.
- Gagne, W. C., and L. W. Cuddihy. 1990. Vegetation. Pages 45-114 in W. L. Wagner, D. R. Herbst, and S. H. Sohmer, editors. Manual of the flowering plants of Hawai'i. University of Hawai'i Press, Honolulu.
- 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 Hawai'i. *Bulletin of the American Meteorological Society* 94:313-316.

- Giambelluca, T. W., R. E. Martin, G. P. Asner, M. Huang, R. G. Mudd, M. A. Nullet, J. K. DeLay, and D. Foote. 2009. Evapotranspiration and energy balance of native wet montane cloud forest in Hawai'i. *Agricultural and Forest Meteorology* 149:230-243.
- Giffin, J. G. 2003. Pu'u Wa'awa'a Biological Assessment. Hawai'i Department of Land and Natural Resources. Division of Forestry and Wildlife.
- Giffin, J. G. 2009. Pu'u Wa'awa'a Biological Assessment. State of Hawai'i, Department of Land and Natural Resources. Division of Forestry and Wildlife.
- Guerrant, J. R., E. O. Fielder, P. L. Havens, and M. Maunder. 2004. Revised genetic sampling guidelines for conservation collections of rare and endangered plants. Pages 419-441 *in* E. O. Guerrant, P. Fiedler, K. Havens, and M. Maunder, editors. *Ex Situ Plant Conservation: supporting species survival in the wild*. Island Press.
- Hess, S. C., and P. C. Banko. 2011. Sheep vs. Palila on Mauna Kea. After 200 years of habitat damage, can native palila recover? *The Wildlife Professional* 5:60-63.
- Hess, S. C., and J. D. Jacobi. 2011. The history of mammal eradications in Hawai'i and the United States associated islands of the Central Pacific. Pages 67-73 *in* C. R. Veitch, M. N. Clout, and D. R. Towns, editors. *Island invasives: eradication and management*. ICUN, Gland, Switzerland.
- Hobdy, R. W. 2014. Botanical and Fauna Survey for The Ka'onoulu Housing Project. Prepared for: Pacific West Communities, Kokomo, Maui.
- Holling, C. S. 1978. *Adaptive environmental assessment and management*. Blackburn Press.
- HPPRCC. 1994. Minutes of the July 7 and 8, 1994, meeting of the Hawai'i and Pacific Plants Recovery Coordinating Committee. Prepared for the U.S. Fish and Wildlife Service. Unpublished.
- Hughes, F., and P. M. Vitousek. 1993. Barriers to shrub reestablishment following fire in the seasonal submontane zone of Hawai'i. *Oecologia* 93:557-563.
- Hughes, F., P. M. Vitousek, and T. Tunison. 1991. Alien grass invasion and fire in the seasonal submontane zone of Hawai'i. *Ecology* 72:743-747.
- IPPC. 2007. Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland.
- ISSG. 2010. *A Compilation of Information Sources for Conservation Managers*. Invasive Species Specialist Group.
- Jacobi, J. D. 2003. Baseline Vegetation Survey and Long-term Monitoring Strategy for the Kipuka Alala Section of the U.S. Army's Pohakuloa Training Area, Island of Hawai'i. U.S. Geological Survey, Pacific Island Ecosystems Research Center, Kilauea Field Station, Hawaii National Park, HI.
- Janzen, D. H. 1988. Tropical dry forests, the most endangered major tropical ecosystem. Pages 130-144 *in* E. O. Wilson, editor. *Biodiversity*. National Academy Press, Washington, DC.
- Juvik, J. O., and L. K. Tango. 2003. Climate and water resources of Pu'u Wa'awa'a, North Kona, Hawai'i. Department of Land and Natural Resources, Division of Forestry and Wildlife.
- Keith, L., R. Hughes, L. Sugiyama, W. Heller, B. Bushe, and J. Friday. 2015. First Report of *Ceratocystis* wilt on 'ōhi'a (*Metrosideros polymorpha*). *Plant Disease* 99:1276.
- Kirch, P. V. 1982. The impact of the prehistoric Polynesian on the Hawaiian ecosystem. *Pacific Science* 36:1-14.

- Kitching, I. J., and J. M. Cadiou. 2000. *Hawkmoths of the World*. Comstock Publishing Associates, Ithica, NY.
- LaPointe, D. A. 2006. Feral pigs, introduced mosquitos, and the decline of Hawai'i's native birds. U.S. Department of the Interior, United States Geological Survey, Technical Report FS 2006-3029.
- Lau, L. K. S., and J. F. Mink. 2006. *Hydrology of the Hawaiian Islands*. University of Hawai'i Press, Honolulu, Hawai'i.
- Letman, J. 2012. Finders Keepers. Pages 20-27 *The Bulletin of the National Tropical Botanical Garden*. National Tropical Botanical Garden.
- Loope, L. L. 1998. *Hawai'i and the Pacific Islands*. U.S. Department of the Interior, U.S. Geological Survey, Reston, Va.
- MacDonald, G. A., and A. T. Abbott. 1970. *Volcanoes in the Sea: The Geology of Hawai'i*. University of Hawai'i Press, Honolulu.
- Maly, K., and O. Maly. 2006. *He Wale Mo'olelo no Pu'u Wa'awa'a a me Nāpu'u o nā kona- A collection of Cultural and Historical Accounts of Pu'u Wa'awa'a and the Nāpu'u Region-District of Kona, on the Island of Hawai'i*. Kumu Pono Associates LLC, Hilo, Hawai'i.
- Maly, K., B. K. Pang, and C. P. M. Burrows. 2013. Pigs in Hawai'i, from Traditional to Modern.
- McDougall, I., and D. A. Swanson. 1972. Potassium-argon Ages from the Hawi and Pololu Volcanic Series. *Bulletin of the Geological Society of America* 83:3731-3738.
- Mehrhoff, L. A. 1988. *Endangered and threatened species. Atlas of Hawai'i, Third Edition edition*. University of Hawai'i Press, Honolulu, Hawai'i.
- Miles, L., A. C. Newton, R. S. DeFries, C. Ravilious, I. May, S. Blyth, V. Kapos, and J. E. Gordon. 2006. A global overview of the conservation status of tropical dry forests. *Journal of Biogeography* 33:491-505.
- Miller, T. E., and J. Travis. 1996. The Evolutionary Role of Indirect Effects in Communities. *Ecology* 77:1329-1335.
- Montgomery, S. L. 1975. Comparative Breeding Site Ecology and the Adaptive Radiation of Picture-winged Drosophila in Hawai'i. *Proceedings of the Hawaiian Entomological Society* 22:65-103.
- Moore, J. G., and D. A. Clague. 1992. Volcano Growth and Evolution of the Island of Hawai'i. *Bulletin of the Geological Society of America* 104:1471-1484.
- Moore, R. B., D. A. Clague, M. Rubin, and W. A. Bohrsen. 1987. *Hualālai Volcano: A Preliminary Summary of Geologic, Petrologic, and Geophysical Data*. Pages 571-585 *Volcanism in Hawai'i*. U. S. Geological Survey Professional Paper 1350. U.S. Government Printing Office.
- Murphy, P. G., and A. E. Lugo. 1986. Ecology of tropical dry forest. *Annual Review of Ecology and Systematics* 17:67-88.
- Nelson, S., and K. Sewake. 2008. Volcanic Emissions Injury to Plant Foliage. Pages 1-11. *Department of Plant and Environmental Protection Sciences. College of Tropical Agriculture and Human Resources, University of Hawai'i at Manoa, Honolulu, Hawai'i* 96822.
- Nogueira-Filho, S., S. Nogueira, and J. Fragoso. 2009. Ecological impacts of feral pigs in the Hawaiian Islands. *Biodiversity Conservation* 18:3677-3683.
- Nunez, M. A., J. K. Bailey, and J. A. Schweitzer. 2010. Population, community and ecosystem effects of exotic herbivores: a growing global concern. *Biological Invasions* 12:297-301.

- Parsons, E., E. Adkins, K. Knoche, T. Seely, J. Crosson, L. Perry, C. Talsma, J. Lawson, and W. Brawner. 2014. Assessing the progress of a dry forest restoration project at Pu'u Wa'awa'a, Hawai'i. *Hawai'i Botanical Forum*, Honolulu.
- Peterson, D. W., and R. B. Moore. 1987. Geologic History and Evolution of Geologic Concepts, Island of Hawai'i. Pages 149-186 *in* R. W. Decker, T. L. Wright, and P. H. Stauffer, editors. *Volcanism in Hawai'i*. U. S. Geological Survey Professional Paper 1350. Government Printing Office.
- Price, J., J. Jacobi, S. M. Gon, D. Matsuwaki, L. Mehrhoff, W. Wagner, M. Lucas, and B. Rowe. 2012. Mapping plant species ranges in the Hawaiian islands - Developing a methodology and associated GIS layers. USGS Open File report 2012-1192.
- Ripley, S. D. 1974. Report on Endangered and Threatened Plant Species of the United States: Presented to the Congress of the United States of America by the Secretary Government Printing Office.
- Rock, J. F. 1913. *The Indigenous Trees of the Hawaiian Islands*. Patronage, Honolulu, HI.
- Sadler, J. P. 1999. Biodiversity and oceanic islands: a palaeoecological assessment. *Journal of Biogeography* 26:75-87.
- Scowcroft, P. G., and J. G. Giffin. 1983. Feral herbivores suppress mamane and other browse species on Mauna Kea, Hawai'i. *Journal of Range Management* 36:638-645.
- Seddon, P. J., W. M. Strauss, and J. Innes. 2012. *Animal Translocations: What Are They and Why Do We Do Them*. First edition. Blackwell Publishing Ltd.
- Shaw, R. B., J. M. Castillo, and B. F. Close. 1997. Rare plant survey of dry montane forest ecosystems, north Kona district, Hawai'i. Center for the Ecological Management of Military Lands. Colorado State University, Fort Collins.
- Sherrod, D. R., J. M. Sinton, S. E. Watkins, and K. M. Brunt. 2007. *Geologic Map of the State of Hawai'i*. U.S. Geological Survey.
- Sohmer, S. H., and R. Gustafson. 1987. *Plants and Flowers of Hawai'i*. University of Hawai'i Press, Honolulu, Hawai'i.
- Spear, D., and S. L. Chown. 2009. Non-indigenous ungulates as a threat to biodiversity. *Journal of Zoology* 279:1-17.
- Springer, H. 2012. Connections: Makai, Mauka, and Mo'okuauhau. Oral presentation in the 20th Hawaii Conservation Conference, Honolulu, HI. Symposium: The ecology and Conservation of Tropical Dry Forests in Hawai'i, moderated by Dr. Elliott Parsons.
- Stone, C. P. 1984. Alien animals in Hawaii's native ecosystems: toward controlling the adverse effects of introduced vertebrates. Pages 251-297 *in* C. P. Stone and J. M. Scott, editors. *Hawaii's Terrestrial Ecosystems: Preservation and Management*. Proceedings of symposium, June 5-6. Cooperative National Park Resources Studies Unit, University of Hawaii, Hawaii Volcanoes National Park.
- Stone, C. P. 1989. Non-native land vertebrates. Pages 88-95 *in* C. P. Stone and D. B. Stone, editors. *Conservation biology in Hawai'i*. Cooperative National Park Resources Studies Unit, University of Hawai'i, Honolulu.
- Stone, C. P., and S. J. Anderson. 1988. Introduced animals in Hawaii's Natural Areas. Proceedings of the Thirteenth Vertebrate Pest Conference, Paper 28:134-140.
- Symon, D. E. 1990. Solanaceae. Pages 1251-1278 *in* W. L. Wagner, D. R. Herbst, and S. H. Sohmer, editors. *Manuel of the Flowering Plants of Hawai'i*. University of Hawai'i Press and Bishop Museum Press, Honolulu, Hawai'i.

- Takeuchi, W. 1991. Botanical Survey of Pu‘u Wa‘awa‘a Final Report. Division of Forestry and Wildlife, Department of Land and Natural Resources.
- Thaxton, J. M., C. T. Cole, S. Cordell, R. J. Cabin, D. R. Sandquist, and C. M. Litton. 2010. Native species regeneration following ungulate exclusion and nonnative grass removal in a remnant Hawaiian dry forest. *Pacific Science* 64:533-544.
- Timm, O., and H. F. Diaz. 2009. Synoptic-statistical approach to regional downscaling of IPCC twenty-first century climate projections: seasonal rainfall over the Hawaiian Islands. *Journal of Climate* 22:4261-4280.
- TNC. 1992. Botanical Survey of Selected Portions of the Pu‘u Wa‘awa‘a Game Management and Lease Area, Island of Hawai‘i. Page 50. The Nature Conservancy. State of Hawai‘i. Division of Forestry and Wildlife.
- Tomich, P. Q. 1969. Mammals in Hawaii. Bernice P. Bishop Museum Special Publication 57. Bishop Museum Press, Honolulu.
- Tomich, P. Q. 1986. Mammals in Hawaii. Bishop Museum Press, Honolulu.
- USDA. 1973. Soil Survey of Island of Hawai‘i, State of Hawai‘i. Map Sections 67 & 68. Soil Conservation Service in Cooperation with the University of Hawai‘i, Agricultural Experiment Station, U. S. Government Printing Office.
- USDA. 2012. Field Guide to Managing Fountain Grass in the Southwest. Pages 1-12. United States Department of Agriculture.
- USFWS. 1984. Endangered and Threatened Wildlife and Plants; Determination of Endangered Status and Critical Habitat for *Kokia drynarioides* (koki‘o). U.S. Fish and Wildlife Service, Department of the Interior.
- USFWS. 1993. Draft Recovery Plan for *Haplostachys haplostachya* and *Stenogyne angustifolia*. U.S. Fish and Wildlife Service, Portland, OR.
- USFWS. 1994. Recovery Plan for *Caesalpinia kawaiensis* and *Kokia drynarioides*. U.S. Fish and Wildlife Service, Portland, OR.
- USFWS. 1996a. Big Island II: Addendum to the Recovery Plan for the Big Island Plant Cluster. U.S. Fish and Wildlife Service, Portland, OR.
- USFWS. 1996b. Recovery Plan Big Island Plant Cluster. U.S. Fish and Wildlife Service, Portland, OR.
- USFWS. 1996c. Recovery Plan for the Molokai Plant Cluster. U.S. Fish and Wildlife Service, Portland, OR.
- USFWS. 1998a. Big Island II: Addendum Recovery Plan for the Big Island Plant Cluster. U.S. Fish and Wildlife Service, Portland, OR.
- USFWS. 1998b. Final Recovery Plan for Four Species of Hawaiian Ferns. U.S. Fish and Wildlife Service, Portland, OR.
- USFWS. 1999. Recovery Plan for Multi-Island Plants. Page 206 pages + appendices. U.S. Fish and Wildlife Service, Portland, OR.
- USFWS. 2000. Availability of a Final Addendum to the Handbook for Habitat Conservation Planning and Incidental Take Permitting Process; Notice. Department of the Interior. Fish and Wildlife Service. National Oceanic and Atmospheric Administration. Department of Commerce.
- USFWS. 2003a. Biological Opinion of the U.S. Fish and Wildlife Service for Routine Military Training and Transformation of the 2nd Brigade 25th Infantry Division (Light) U.S. Army Installations Island of Hawai‘i. U.S. Fish and Wildlife Service.

- USFWS. 2003b. Draft Recovery Plan for the Blackburn's Sphinx Moth (*Manduca blackburni*). U.S. Fish and Wildlife Service, Portland, OR.
- USFWS. 2003c. Endangered and Threatened Wildlife and Plants; Final Designation and Nondesignation of Critical Habitat for 46 Plant Species From the Island of Hawaii, HI; Final Rule. Federal Register Department of the Interior. U.S. Fish and Wildlife Service.
- USFWS. 2009. *Kokia drynarioides* (Koki'o) U.S. Fish and Wildlife Service, Honolulu, HI.
- USFWS. 2010. *Silene lanceolata*. U.S. Fish and Wildlife Service Honolulu, HI.
- USFWS. 2012a. *Asplenium peruvianum* var. *insulare* 5 - Year Review Summary and Evaluation U.S. Fish and Wildlife Service, Honolulu, HI.
- USFWS. 2012b. *Haplostachys haplostachya* (Honohono). U.S. Fish and Wildlife Service, Honolulu, HI.
- USFWS. 2012c. *Nothocestrum breviflorum* (Aiea). U.S. Fish and Wildlife Service, Honolulu, HI.
- USFWS. 2012d. *Pleomele hawaiiensis* (Hala pepe) 5 - Year Review Summary and Evaluation U.S. Fish and Wildlife Service, Honolulu, HI.
- USFWS. 2012e. *Portulaca sclerocarpa* (Poe). U.S. Fish and Wildlife Service, Honolulu, HI.
- USFWS. 2012f. *Stenogyne angustifolia* 5 - Year Review Summary and Evaluation U.S. Fish and Wildlife Service, Honolulu, HI.
- USFWS. 2015a. 5 - Year Review Short Form Summary *Caesalpinia kavaiensis* (Uhiuhi). U.S. Fish and Wildlife Service, Honolulu, HI.
- USFWS. 2015b. 5 - Year Review Short Form Summary *Neraudia ovata* (no common name). U.S. Fish and Wildlife Service, Honolulu, HI.
- USFWS. 2015c. 5 - Year Review Short Form Summary *Solanum incompletum* (popolo ku mai). U.S. Fish and Wildlife Service, Honolulu, HI.
- USFWS. 2015d. 5 - Year Review Short Form Summary *Zanthoxylum hawaiiense* (a'e). U.S. Fish and Wildlife Service, Honolulu, HI.
- USFWS. 2015e. Biological Opinion for Clearing of Fire Roads and Fuel Breaks at Pu'u Wa'awa'a Forest Reserve and Pu'u Anahulu Game Management Area, Hawai'i. United States Department of the Interior. U.S. Fish and Wildlife Service, Honolulu, HI.
- USFWS. 2015f. *Colubrina oppositifolia* (kauila). U.S. Fish and Wildlife Service, Honolulu, HI.
- Wagner, W. L., D. R. Herbst, and S. H. Sohmer. 1999. Manual of the Flowering Plants of Hawai'i. Revised edition. University of Hawai'i Press, Honolulu, HI.
- Walker, G. P. 1990. Geology and Volcanology of the Hawaiian Islands. *Pacific Science* 44:315-347.
- Webster, P. J., G. J. Holland, J. A. Curry, and H. R. Chang. 2005. Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment. *Science* 309:1844-1846.
- Williams, J. 1980. Native vs. exotic woody vegetation recovery following goat removal in the eastern coastal lowlands of Hawaii Volcanoes National Park. Pages 373-382 in *Proceedings of the Third Conference in Natural Sciences Hawaii Volcanoes National Park*. University of Hawaii at Manoa, Department of Botany, Volcanoes National Park.
- Wolfe, E. W., and J. Morris. 1996. Geologic Map of the Island of Hawai'i. U.S. Geological Survey Miscellaneous Investigation Series I-2524-A, 18 p.3.
- Yarrow, G. K., and D. T. Yarrow. 1999. *Managing Wildlife*. Sweetwater Press, Birmingham, AL.
- Ziegler, A. C. 2002. *Hawaiian natural history, ecology, and evolution*. University of Hawai'i Press, Honolulu, HI.

