# Hawaiian Hoary Bat
# Tier 1 Mitigation
# Habitat Management Plan
# for the Poamoho Management Area

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# 1.0 Introduction

The Nā Pua Makani Wind Project (Project) Habitat Conservation Plan (HCP) was approved by the Board of Land and Natural Resources (BLNR) in May 2018, and Nā Pua Makani Power Partners, LLC (NPMPP) was issued an associated federal Incidental Take Permit and state Incidental Take License. As described in the HCP, to mitigate for potential impacts to 34 Hawaiian hoary bats (*Lasiurus semotus*) or ʻōpeʻapeʻa under the Tier 1 take scenario, NPMPP identified a plan consisting of a combination of habitat management and research (Tetra Tech 2016). The habitat management component would be the primary approach to mitigate for potential impacts to bats, and the research component would help regulatory agencies and land managers better understand the impacts of the management actions. The Tier 1 habitat management component in the HCP states that NPMPP would fund eight years of management and monitoring efforts to be conducted by staff of the Koʻolau Mountains Watershed Partnership (KMWP) in the state Poamoho Management Area (PMA). The Tier 1 habitat management components are described in this document (Habitat Management Plan); the Habitat Management Plan's goal is to support protection of the area from the impacts of invasive species that are expected to negatively affect bat foraging and potentially roosting resources without intervention. The Tier 1 research program is described in a separate document, Hawaiian Hoary Bat Tier 1 Mitigation Research Plan (Research Plan; Tetra Tech 2024). The goal of the Research Plan is to augment our understanding of how the management actions described in this Habitat Management Plan benefit bats.

The PMA was selected for several reasons. Although the Hawaiʻi Department of Land and Natural Resources (DLNR) had funding to support the fencing of the area, the DLNR did not have secure funding for long-term forest restoration and management of this parcel including maintenance of the fence constructed by DLNR, on-going feral pig (*Sus scrofa*) management, if required, and invasive plant species management; thus, the need exists for secure funds to ensure protection and recovery of bat habitat. The specific quantification of the area to be managed and its relationship to the number of bats benefited through the mitigation actions is described in the Project HCP and was based on guidance from the U.S. Fish and Wildlife Service (USFWS) and DLNR—Division of Forestry and Wildlife (DOFAW) (DOFAW 2015, Tetra Tech 2016). The U.S. Fish and Wildlife Service issued an Incidental Take Permit for the Project based on their review and approval of the HCP and the proposed bat mitigation program, and BLNR, upon review and recommendation for approval by DOFAW and the Endangered Species Recovery Committee (ESRC), approved the HCP and issued an Incidental Take License.

Bats have been documented within the PMA via acoustic monitoring efforts initiated by the Project in coordination with KMWP and DLNR in April 2014, and nearby monitoring studies have subsequently documented bats in similar habitats (Tetra Tech 2016, Davidson 2020, Thompson and Starcevich 2022). Given the on-going threats from feral pigs and invasive plants, this habitat has been negatively impacted and will continue to degrade without active and consistent management. Protection from impacts of feral pigs and invasive plant removal will interrupt the habitat degradation and increase the quality of the habitat inside the fence. The restoration and management activities will foster the growth of additional bat roosting and foraging habitat and will support a diverse native species dominated forested corridor connected to the Ahupua ʻ a O Kahana State Park and forested habitat managed for conservation in neighboring military reservation areas. Finally, restoration efforts in a native forest that is under pressure from non-native plants and ungulates provide an opportunity to develop a better understanding of the potential benefits of this type of forest restoration project to the Hawaiian hoary bat. This opportunity is leveraged through the Research Plan, which expands on monitoring for the direct effects of the management actions to pursue a deeper understanding of the mechanisms behind the conservation benefits (Tetra Tech 2024). The result of this improved understanding will help guide the effective allocation of future management resources.

The benefits envisioned include providing on-going protection during the period of performance to reduce the risk of new invasive species gaining a foothold, removal of invasive plants to allow natural restoration processes to reclaim areas impacted by invasive plant species, and maintaining the pig proof fence that contributes to protection of this environment. These actions are expected to increase available bat prey and result in an associated increase in bat acoustic activity within the managed area, which will be determined via the monitoring program described in this Habitat Management Plan.

This Habitat Management Plan:

- Describes relevant Hawaiian hoary bat information that provide a theoretical understanding of how bats are expected to benefit from management actions proposed for this mitigation project;
- Describes the baseline condition of the PMA;
- Details the management actions to be carried out for this mitigation project;
- Details the monitoring plan that will measure expected outcomes;
- Details specific measures of success that will be used to evaluate successful implementation of the mitigation project; and
- Identifies potential adaptive management actions to address the identification of conditions that suggest the mitigation project is not providing the expected benefits to bats on the anticipated timeline.

# 2.0 Mitigation Framework

As described in Section 1.0, the Project's Tier 1 bat mitigation plan is comprised of two elements: the Habitat Management Plan (this document) and the Research Plan (Tetra Tech 2024). The Habitat Management Plan monitoring is designed to 1) document the increases in bat acoustic activity within the management area and 2) document increases in availability of prey species associated with changes in the vegetation community achieved through habitat management. The associated Research Plan adds a control study to the Habitat Management monitoring program to increase understanding of how and when the management efforts yield benefits (Tetra Tech 2024). These two elements work in tandem to achieve and document direct benefits to the Hawaiian hoary bat and to gather additional detail on the mechanism for those benefits that should help guide the effective allocation of future management resources.

Based on input from USFWS and DOFAW during the development of the HCP, this blended approach is focused primarily on habitat management actions; however, given the novel threats and condition of the PMA, both agencies and the ESRC reinforced the importance of developing a more robust understanding of the effects of these actions than would be achieved through standard evaluative monitoring. This Habitat Management Plan specifically evaluates whether actions to protect and restore habitat and bat prey resources increase acoustic activity (i.e., detection rate) by the Hawaiian hoary bats through an evaluative monitoring program. Increases in acoustic activity may be demonstrated through a variety of lenses such as detecting changes in vocalizations that signify changes in foraging and roosting activity from the baseline. Teixeria et al. (2019) suggests that vocalizations can serve as indicators of behavioral states and contexts that provide insight into populations as it relates to their conservation. Leveraging this observation, the evaluative monitoring plan (Section 6.2) includes evaluation of the types, duration, temporal patterns, and seaonality of calls to reveal changes in these patterns, relecting changes in the way bats use the PMA over time.

## 2.1 Biological Goals and Objectives

The purpose of identifying biological goals and objectives is to establish a framework (USFWS and NMFS 2016) for developing the mitigation actions and success criteria for this Habitat Management Plan. Biological goals are intended to be broad, guiding principles that clarify purpose and direction. Biological objectives are derived from the goals and provide the basis for determining strategies, monitoring effectiveness, and evaluating the success of actions (USFWS and NMFS 2016). The Habitat Management Plan's success criteria (Section 8.0) are then derived from these objectives. Interim time-based metrics are integrated into an adaptive management strategy (Section 9.0); if the interim metrics are met, the mitigation plan will be on track for meeting the biological goals and objectives. The biological goals and objectives for this Habitat Management Plan are shown in Table 1.

**Table 1. Biological Goals and Objectives**

| | |
|---|---|
| **Biological Goal: Fully offset the incidental take of 34 Hawaiian hoary bats required for Tier 1 mitigation and provide a net benefit to the species.** | |
| **Biological Objective** | Enhance, manage, and protect 1,307 acres of Hawaiian hoary bat foraging and roosting habitat at the Poamoho Management Area (see Success Criteria 1 and 2; Section 8.0) |
| **Biological Objective** | Demonstrate that habitat enhancement is linked to an increase in bat prey availability (See Success Criteria 3; Section 8.0) |
| **Biological Objective** | Demonstrate an increase in bat activity indicative of resource improvement and availability for bats. (See Success Criteria 4; Section 8.0) |
| **Biological Goal: Restore structural diversity and prevent further deterioration of Hawaiian hoary bat foraging habitat in the Poamoho Management Area** | |
| **Biological Objective** | Increase the total area of quality habitat for Hawaiian hoary bat by restoring 1,307 acres of foraging and roosting habitat at the Poamoho Management Area for 8 years (see Success Criteria 1 and 2; Section 8.0). |
| **Biological Objective** | Manage and monitor focal invasive plant species within the Poamoho Management Area for 8 years (see Success Criteria 2; Section 8.0). |
| **Biological Objective** | Implement best management practices to avoid the introduction or spread of invasive plant species in the Poamoho Management Area for 8 years. |
| **Biological Goal: Reduce invasive plant species cover to significantly increase bat prey availability in the Poamoho Management Area for the Hawaiian hoary bat** | |
| **Biological Objective** | Increase the diversity of native plants within the Poamoho Management Area by Year 8 by reducing invasive plant species (see Success Criteria 1 and 2; Section 8.0). |
| **Biological Objective** | Ensure continued eradication of feral ungulates in the Poamoho Management Area for 8 years. |
| **Biological Objective** | Monitor bat prey availability in Years 1, 3, 5 ,and 8 and adaptively manage in Years 5 and 8 (if needed). |
| **Biological Goal: Increase native biological diversity to significantly increase Hawaiian hoary bat activity in the Poamoho Management Area** | |
| **Biological Objective** | Implement best management practices to minimize the risk of the spread of the plant pathogen responsible for Rapid ʻŌhiʻa Death for 8 years. |
| **Biological Objective** | Increase native plant recruitment to enhance Hawaiian hoary bat habitat in the Poamoho Management Area by year 8. |
| **Biological Objective** | Monitor bat acoustic activity between sunset and sunrise in Years 1, 3, 5 ,and 8 and adaptively manage in Years 5 and 8 (if needed). |

The biological objectives in Table 1 track increases in bat acoustic activity and insect prey as surrogates for the direct number of bats identified in the biological goal. The Hawaiian hoary bat, like many species of bats, is a nocturnal cryptic mammal that is difficult to study. Currently, it is not yet possible to use acoustic data to make any inferences about population abundance or densities as individuals cannot be reliably identified from acoustic data alone (Poe 2007, Hayes et al. 2009, Frick 2013, Fill et al. 2023). For example, it is not possible to know if 10 bat passes represent 10 bats or one bat passing 10 times (Frick 2013). However, there is a vast amount of conservation-relevant information that can be derived from acoustic signatures associated with particular behaviors (Teixeira et al. 2019). In bats, acoustic signatures can be used to identify various states of foraging behavior (i.e., active or passive) or feeding rates, socializing, and grouping behavior (i.e., multiple individuals). When combined with knowledge on the timing of key life-history stages, vocal behaviors from acoustic data can be used to identify important habitats for reproductive success. Examining the spatial and temporal trends in vocal behaviors through acoustic monitoring can provide a means to assess habitat quality, evaluate the effectiveness of conservation actions, and identify factors in the environment that could be adaptively managed (Teixeira et al. 2019).

# 3.0 Hawaiian Hoary Bat Background

The Hawaiian hoary bat, a solitary tree roosting bat, occurs on all the major Islands in the Hawaiian Archipelago, Kauaʻi, Oʻahu, Maui, Lānaʻi, Molokai, and Hawaiʻi (Tomich 1986). Recent significant investments in research and preliminary results from management efforts have provided significant insights into habitat use, tree roost characteristics, diet, population dynamics, seasonal occupancy and foraging ranges on the islands of Oʻahu, Maui, and Hawaiʻi. Significant knowledge gaps related to the species' life history, survival, sex and distributions, and population size, remain, but findings from these studies and other research can be leveraged to manage and protect habitat in ways that are likely to enhance habitat suitability for the bat. Below we summarize actionable knowledge about the bat.

## 3.1 Distribution, and Population Trends

On Hawaiʻi Island hoary bats have been shown to migrate along altitudinal gradients in response to changes in temperature, rainfall, and food resources, occupying low elevations during the summer and fall breeding seasons and migrating to the interior highlands during the winter post-lactation period (Menard 2003, Todd 2012, Bonaccorso et al. 2015). Seasonal changes in acoustic activity observed at several locations on Oʻahu (Gorresen et al. 2015, Thompson and Starcevich 2022) and Maui (Todd et al. 2016, H.T. Harvey 2020, Auwahi Wind 2023, Tetra Tech 2023a, Tetra Tech 2023b) suggest similar altitudinal migrations occur on these islands.

An occupancy study conducted on Hawaiʻi Island suggest that population is stable and potentially increasing (Gorresen at al. 2013). An occupancy study on Oʻahu suggested the population on that island also appeared stable to slightly increasing over the study period (Thompson and Starcevich

2022). Estimates of contemporary genetic effective population sizes[1] indicate population sizes are greater on Hawaiʻi Island and Kauaʻi than on Maui and Oʻahu and that there has been little to no cotemporary gene flow between islands (Pinzari et al. 2023). Estimates of population size can be extremely difficult for cryptic species like the Hawaiian hoary bat and currently no estimates of population size have been conducted for the species with a high level of confidence.

## 3.2 Life history information related to habitat management

Bats are highly mobile and capable of flying large distances quickly. This mobility gives them access to a wide range of habitats and can reduce their dependence upon a particular setting. For some bat species there are clear associations with specific habitats (Russo and Jones 2003, Fenton et al. 1992, Racey 1998) while others are more flexible in their use of habitats (Russo and Jones 2003, Rautenbach et al. 1996). Habitat selection by bats can be influenced by a variety of intrinsic (i.e., life history) and extrinsic (i.e., weather) factors. However, the two primary factors that determine habitat selection by bats are availability of adequate roost sites and the abundance or ability to capture prey (Fenton 1997). Male and female bats have been captured at low and high elevations with peak capture rates occurring at 930 meters (Hoeh et al. 2023)

The Hawaiian hoary bat is regarded as a generalist species and demonstrates considerable flexibility in its use of native and non-native habitats for foraging and roosting. Radio telemetry studies on Hawaiʻi Island have documented the hoary bat traversing greater than 17 kilometers from its roost site to forage among a mosaic of habitat elements such as the edges of cluttered forests and within open spaces including forest gaps, gulches, windrows, roadways , open water, pastures, and above the forest canopy (Whitaker and Tomich 1983; Belwood and Fullard 1984; Jacobs 1996, 1999; Poe 2007; Bonaccorso et al. 2015). These sites provide sheltered foraging grounds on windy nights and facilitate easy capture of prey.

Hoary bats are known to forage on a variety of insects from 10 orders and 24 different families (Todd 2012, Pinzari et al. 2019, H.T. Harvey 2020). However, Lepidoptera—butterflies and moths represent the most abundant and diverse insect taxa in the diet of hoary bats, followed by Coleoptera—beetles(Todd 2012, Pinzari et al. 2019). Following lactation, a period of high energetic demand, Hawaiian hoary bats have been shown to selectively forage on Coleoptera, which may be easier to catch and satisfy additional nutrient demands (Todd 2012). For many bat species including Hawaiian hoary bats, increased rates in activity are associated with increased abundance of insect prey (Knops et al. 1999, Haddad et al. 2001, Todd 2012, Gorresen et al. 2018). On Hawaiʻi Island, female bats were found to be more active during the reproductive season (May to September), while male bats were most active during the non-reproductive season (October to April) (Hoeh et al. 2023).

Roost trees species used by Hawaiian Hoary bats include both native and non-native species. The diversity in roost trees used by Hawaiian hoary bats exists only among non-native species, as the predominant native trees species confirmed as a roost tree by hoary bats is ʻōhiʻa (*Metrosideros*

[1] Effective population estimates are not equivalent to the true “census” population size, and all estimates should be interpreted with caution and subject to change with additional data (

*polymorpha*), with endemic lama (*Diospyros sandwicensis*) and indigenous uluhe (*Dicranopteris linearis*) also being used for roosting but much less frequently (Montoya-Aiona et al. 2023). Habitat use studies of radio tagged bats indicate that Hawaiian hoary bats select roost trees with a height of 14 to 26 meters, diameter at breast height (DBH) of 32 to 268 centimeters, canopy cover of 4 to 99 percent (Montoya-Aiona et al. 2023), and a mean distance of 29 meters from the forest edge (Montoya-Aiona 2020). These results suggest that structure, not species, is the deciding factor determining use by Hawaiian hoary bats. Montoya-Aiona et al. (2023) found that the top model for predicting tree use was tree height and DBH, but only when tall, larger trees had a relatively open canopy and were situated close to the forest edge. Other studies have found that a varied vegetative structure provides shelter for insect species that are the prey for Hawaiian hoary bats, and Hawaiian hoary bats preferred edge habitat for foraging (Jantzen 2012, H.T. Harvey 2020). In addition, monotypic habitats—like stands of strawberry guava (*Psidium cattleyanum*) are associated with reduced bat foraging quality (Fenton 1997, Williams et al. 2006).

# 4.0 Poamoho Management Area

The PMA and adjacent ʻEwa Forest Reserve is primarily DLNR-owned forested habitat extending through mid-elevation habitat to the leeward summit of the central Koʻolau Mountains[2]. The PMA is located above Wahiawa in the ʻEwa Forest Reserve (Figure 1) and is proposed to be part of the state Natural Area Reserve System. Native, mid-elevation (490 – 730 meters above sea level) forest occurs in the PMA, but habitat-altering invasive plant species are present over significant areas, and prior to fence construction feral pigs were a significant problem and remain a threat (Figure 2; Tetra Tech 2016). Pigs alter habitat, spread invasive species, and continue to degrade forest in unfenced portions of the ʻEwa Forest Reserve. Ungulate proof fencing has been installed on two parcels, one 654 acres and the other 653 acres. DLNR is responsible for long-term management of the area and relies heavily on KMWP to support management of the area.

The ʻEwa Forest Reserve provides habitat for the Hawaiian hoary bat and use of the area and the vicinity has been documented (Tetra Tech 2016, Davidson 2020, Thompson and Starcevich 2022). The protected PMA includes key Koʻolau Mountains watersheds and key native forest habitat that affords native plants and animals opportunities for protection through active management.

## 4.1 Baseline bat activity

The results from an island-wide acoustic monitoring research project suggests a generally low occupancy rate at the upper elevation of the PMA (average 0.0164 detections/detector-night June 2017 – October 2021) with detections concentrated in the lactation (mid-June – August) and post-lactation (September – mid-December) seasons (Site-046 in Thompson and Starcevich 2022). Another nearby site at a lower elevation (Site-055) included a higher activity rate (0.0398 detections/detector night) and showed a similar temporal distribution of activity (Thompson and

[2] The northern fencing unit of the PMA includes 70 acres on Kamehameha Schools’ property within the Kawailoa Training Military Reservation.

Starcevich 2022). Results from the detectors distributed more broadly within the Koʻolau Mountains suggest that bats are likely present at low levels throughout the year with the lowest occupancy rates occurring during the pregnancy season (April – mid-June). Baseline activity for the purposes of evaluating mitigation success criteria and triggering adaptive management will be based on Year 1 results from monitoring associated with this Habitat Management Plan (Section 6.2).

## 4.2 Threat assessment

Invasive plants, plant pathogens, and feral ungulates all present threats that could impact bats by degrading foraging and roosting habitat. An overview of the current condition of the PMA and the mechanism for how these threats can impact bat foraging and roosting habitat are described below.

### *4.2.1 Invasive plants*

Invasive plants are a serious threat to the ecosystems of Hawaiʻi due to their capacity to displace native species and disrupt natural cycles that produce freshwater for the island (Loope 1998). The establishment of invasive plants can result in higher rates of erosion, increased sedimentation in streams, and decreased recharge, especially when monotypic vegetation stands are formed (e.g., Kauaʻi Invasive Species Committee 2015, Kaiser et al. 2019).

Thirty established invasive plant species have been identified throughout the PMA (Table 2) during recent surveys conducted by KMWP. The five species in Table 2 with an "X" in the Focal Management Column will be the focus of control efforts because each of these species are becoming well-established in the PMA and have the potential to significantly affect habitat quality and diversity if not aggressively managed. The mule's foot fern (*Angiopteris evecta*) is the most prevalent priority weed species in Poamoho.(Figure 2). Strawberry guava has also become well established, particularly in the northern section of the management area and in several clusters throughout the eastern and southern portions of the management area (Figure 2). Additionally, patches of manuka (*Leptospermum scoparium*) have become established along the northern border of the PMA along with incipient populations of Moluccan albizia (*Falcataria falcata*) and cane tibouchina (*Chaetogastra herbacea*; Figure 2). The remaining twenty-five invasive plant species in Table 2 will be monitored and adaptively managed during implementation of this Habitat Management Plan if they increase in extent and density so that they begin to affect habitat quality and diversity.

The invasive plant species in Table 2 can be aggressive invaders forming dense stands that enable them to outcompete native species for light and soil nutrients, leading to a reduction in the biodiversity of native plant species. (Funk 1987, Wilson 1996, Hughes and Denslow 2005, Allison et al. 2006, Christenhusz and Toivonen 2008, Atwood et al. 2010, Global Invasive Species Database 2020a, Global Invasive Species Database 2020b). Together, competition from these invasive species pose a major threat to the recruitment of many native plant species including ʻōhiʻa, a keystone species and important roost tree for bats, as well as lama and uluhe, which are also used by Hawaiian hoary bats for roosting (Montoya-Aiona et al. 2023).

There also is significant potential for new habitat altering invasive species to become established in the PMA in the absence of active management. Incipient invasions that are not identified early and spread unchecked can present significant management challenges for years to come.

**Table 2. Focal Management Species and Control Method for Established Invasive lant Species in the Poamoho Management Area**

| Scientific Name | Common Name | Method[1] | Herbicide[2] | Focal Management Species |
|---|---|---|---|---|
| *Andropogon virginicus* | broomsedge | Foliar | 2% GLY in $H_2O$ | |
| *Angiopteris evecta* | mule's foot fern | IPA | 10 mls of 100% Polaris applied to multiple cuts on "brain" | X |
| *Ardisia elliptica* | shoebutton ardisia | IPA | 100% Polaris | |
| *Ardisia crenata* | Hilo holly | IPA | 100% GLY | |
| *Arthrostemma ciliatum* | Arthrostemma | Foliar | 2% GLY in $H_2O$ | |
| *Buddleja asiatica* | Asian butterfly bush | IPA | 100% Polaris | |
| *Casuarina equisetifolia* | ironwood | Girdle | 20% G4, 80% MSO | |
| *Cecropia obtusifolia* | trumpet tree | IPA | 100% Polaris | |
| *Citharexylum caudatum* | juniper berry | Cut stump | 30% G4, 70% MSO | |
| *Grevillea robusta* | silky oak | IPA | 100% Polaris | |
| *Hedychium gardnerianum* | Himalayan ginger | Cut | 0.2% Escort, 0.5% Crop oil, 96.5% water, 3% MSO | |
| *Heliocarpus americanus* | white moho | IPA | 100% Polaris | |
| *Lantana camara* | Lantana | Cut stump | 20% G4, 80% MSO | |
| *Leptospermum scoparium* | manuka | Cut | Cut-Stump | X |
| *Melaleuca quinquenervia* | paperbark tree | IPA | 30% Polaris in $H_2O$ | |
| *Falcataria falcata* | Mollucan albizia | IPA | 100% AMP | X |
| *Passiflora laurifolia* | Jamaican honeysuckle | Cut stump | 20% G4, 80% MSO (cut stump) | |
| | | Foliar | 2% GLY (foliar) | |
| *Cenchrus setaceus* | fountain grass | Foliar | 3% GLY in $H_2O$ | |
| *Pluchea carolinensis* | sourbush | Basal bark | 20% G4, 80% MSO | |
| *Psidium cattleyanum* | strawberry guava | IPA | 30% G4 with 1% Milestone | X |
| *Psidium guajava* | common guava | IPA | 30% G4 with 1% Milestone | |
| *Rubus rosifolius* | Himalayan blackberry | Basal bark | 20% G4, 80% MSO | |
| *Heptapleurum actinophyllum* | umbrella tree | IPA | 100% GLY or 100% Polaris | |

| Scientific Name | Common Name | Method[1] | Herbicide[2] | Focal Management Species |
|---|---|---|---|---|
| *Schinus terebinthifolia* | Christmasberry/Brazilian pepper | IPA | 100% Polaris | |
| *Setaria palmifolia* | palmgrass | Foliar | 2% GLY in $H_2O$ | |
| *Spathodea campanulata* | African tulip tree | IPA | 100% Polaris | |
| *Sphaeropteris cooperi* | Australian tree fern | Cut | Cut-stump | |
| *Toona ciliata* | Australian red cedar | IPA | 100% Polaris | |
| *Chaetogastra herbacea* | cane tibouchina | Clip and drip | 20% G4, 80% MSO | X |
| *Trema orientale* | gunpowder tree | IPA or foliar | 100% Polaris (adult) | |
| | | | 2% GLY in $H_2O$ (saplings) | |

[1] IPA = incision point application.

[2] GLY = glyphosate; G4 = Garlon 4; MSO = methylated seed oil surfactant.

### 4.2.2 *Plant pathogens*

In Hawaiʻi, the most notorious plant pathogens to date are vascular wilt fungus (*Ceratocystis lukuohia*) and the canker pathogen (*Ceratocystis huliohia*). These two recently described species are responsible for causing Rapid ʻŌhiʻa Death (ROD), resulting in the devastating mortality of ʻōhiʻa forests (Barnes et al. 2018).

ʻŌhiʻa is an iconic keystone canopy tree species endemic to Hawaiʻi. It is the most common and widespread native tree species throughout Hawaiʻi, occurring from sea level to 2,500 meters elevation and is a pioneer and foundation species  in both mesic and wet montane forests and on substrates ranging from 50 to 4 million years in age (Friday and Herbert 2006, Loope 2016, Pratt and Jacobi 2009). It is the most ecologically important native tree in Hawaiʻi, defining native forest succession and ecosystem function over broad areas, providing critical habitat for rare and endangered native bird, bat, and insect species, and exemplifying the strong links between native Hawaiian culture and the islands' environment (Dawson and Stemmermann 1990, Gruner 2004, Peck et al. 2014).

The fungal pathogens that trigger ROD cause browning of canopy leaves in weeks to months following infection by the pathogens. Inoculation trials conducted on seedlings indicate that both *Ceratocystis* species are aggressive on ʻōhiʻa. However, field observations on the progression of symptoms in naturally infected trees suggest that *C. huliohia* is less aggressive than *C. lukuohia* (Barnes et al. 2018). *Ceratocystis lukuohia* has now been identified as the main cause of stand-level mortality events, whereas *C. huliohia* is thought to be associated with smaller, more localized mortality events. (Fortini et al. 2019).

First detected in 2010 in the Puna district of Hawaiʻi Island, ROD has since spread to an estimated 40,469 hectares across Hawaiʻi Island, resulting in the death of hundreds of thousands of native

ʻōhiʻa (Keith et al. 2015, Mortenson et al. 2016). In 2018 *C. lukuohia* was confirmed on the Island of Kauaʻi (DLNR 2018) and in July of 2019 a single case of *C. huliohia* was confirmed on Maui and 12 cases of *C. huliohia* were confirmed on Oʻahu, including one in the PMA (DOFAW 2023, University of Hawaiʻi 2023).

The rapid spread of *C. lukuohia* and *C. huliohia* in Hawaiʻi presents a great threat to the diversity, structure, and function of ʻōhiʻa forests and the services they provide. If the disease is not contained, much of the landscape is likely to be replaced by non-native species (Mortenson et al. 2016).

The use of ʻōhiʻa as the primary native roost tree species used by hoary bats in Hawaiʻi (Montoya-Aiona et al. 2023) further highlights its importance as a keystone species. The loss of ʻōhiʻa in the PMA due to ROD would reduce the availability and quality of Hawaiian hoary bat roost trees and could be anticipated to degrade foraging habitat by facilitating further establishment of monotypic invasive species forest stands.

### *4.2.3 Feral ungulates*

Pigs are currently the only feral ungulates occupying habitat in the vicinity of the PMA. They have been eradicated from the PMA; however, periodic damage to the existing ungulate fence creates opportunities for feral pigs to enter the PMA and damage habitat. Therefore, regular fence inspections and maintenance are critical to protecting this area. Feral pigs are one of the most destructive invasive species on islands as their behaviors can have impacts across all levels of an ecosystem and are considered to be one of the primary threats to remnant native wet forests (Cole and Litton 2014).

Feral pigs affect native ecosystems directly through herbivory, rooting and trampling. A single feral pig is capable of disturbing up to 200 meters$^2$/day of forest soil surface (Anderson and Stone 1993). These foraging behaviors substantially increase the area of exposed soil and subsequent soil erosion (Scowcroft and Hobdy 1987, Anderson and Stone 1993, Siemann et al. 2009, Cole et al. 2012), facilitate the invasion of non-native plants species (Ickes et al. 2001, Spear and Chown 2009), and create sites suitable for vectors of avian disease (Stone and Loope 1987, Wehr et al. 2018). Furthermore, feral pigs can increase exposure and transmission of ROD (Mortenson et al. 2016).

Disturbance from feral pigs strongly suppresses establishment of many native Hawaiian species (Cole and Litton 2014) and can result in long-term consequences for plant regeneration (Lipscomb 1989; Mitchell et al. 2007; Webber et al. 2010), forest structure (Busby et al. 2010; Cole et al. 2012), and ecosystem biogeochemistry (Siemann et al. 2009). Controlling feral pigs through active removal and fencing is therefore considered a critical first step for conserving and restoring native rain forests. Recovery of common native species can occur relatively quickly (within 6.5 years) following the removal of feral pigs (Cole and Litton 2014) and the exclusion of feral pigs has been shown to reduce the prevalence and spread of *Ceratocystis*, the pathogen responsible for causing ROD (Fortini et al. 2019).

# 5.0 Management Program

The mitigation program provided by NPMPP includes funding for 2 full-time staff equivalents, equipment, materials, transportation, and mapping support for 8 years of management activities. Based on USFWS and DOFAW guidance, habitat management of the 1,307 acres of habitat in the PMA over this period in combination with an associated $100,000 Research Plan was determined in the Project HCP as sufficient to mitigate for the potential take of 34 bats in Tier 1[3]. This also equates to 38 acres of habitat restoration per bat, exceeding agency recommendations at the time (DOFAW 2015). This section describes the management actions associated with the Management Plan, the results of which are monitored through the monitoring program (Section 6.0) and measured against the success criteria (Section 8.0). Management activities include:

- Invasive vegetation management program
  - Management of priority invasive weed species (sections 4.2.1, 5.1.1)
  - Surveillance and rapid response program to identify and respond to priority incipient invasive species
- Plant pathogen surveillance and response program (sections 4.2.2, 5.1.2)
- Feral ungulate surveillance and management (feral ungulates have been removed from the PMA but threaten incursion into the PMA if fences are damaged [sections 4.2.3, 5.1.3]).
  - Regular fence inspections and maintenance activities
  - Rapid response program to inspect and repair fence as required following storm events
  - Monitoring program to identify and respond to presence of feral ungulates within the management area

It is assumed that the existing native seed bank will reestablish native plants over time in areas where invasive species are removed and managed (Cole and Litton 2014). Supplemental out-plantings would be added if needed, in response to adaptive management triggers (see Section 9.0).

## 5.1 Threat management

This Habitat Management Plan identifies habitat management actions to improve the forest structure and composition of the PMA as a foraging and roosting habitat for the only native bat species in the state. ʻŌhiʻa is the primary native roost tree for Hawaiian hoary bats (USFWS 1998, Gorresen et al. 2013, DLNR 2015, Montoya-Aiona et al. 2023) and the dominant canopy tree in the PMA. As such, the loss of this keystone species could result in a cascade of ecological effects. Invasive plants, feral ungulates, and plant pathogens have previously been identified as the major threats to the watershed (KMWP 2002, 2016).

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[3] The Project HCP (Tetra Tech 2016) provided the calculation: *Required years of forest restoration on 1,307 acres to mitigate at a rate of $50,000/bat based on ESRC Bat Guidance (DOFAW 2015) and accounting for research commitments calculated as ((34 bats)* ($50,000/bat) - $100,000 [Tier 1 research] – 2 * $26,000 [vegetation mapping years 1 and 5])/($198,000 [Annual restoration budget for 1,307 ac]) = 8 yr (rounded).*

The management actions identified to control the major threats to the PMA and improve and protect the habitat for bats are described below. Together these management strategies aim to protect the existing native canopy species while facilitating the recruitment of native understory species.

### *5.1.1 Invasive vegetation*

Thirty established invasive plants species are currently found within the PMA and identified as target species for control by KMWP (Table 2). KMWP has identified mule's foot fern, strawberry guava, manuka, Moluccan albizia, and cane ti as the highest priority target invasive species in the PMA for management due to their level of establishment or their identified risk for causing significant habitat alteration if their spread is left unchecked.

Mule's foot fern is widespread throughout both the northern and southern management areas, whereas strawberry guava is most prevalent along the northern boundary of the northern management section and in several patches within the southern. Mule's foot fern and strawberry guava have had the most widespread effects, significantly reduced the diversity of native plant species where they are found, resulting in monotypic habitats.

Mauka, Moluccan albizia, and cane ti are not as abundant as mule's foot fern and strawberry guava, but if left untreated, these invasive species will be increasingly difficult to control and have a broader impact on forest plant diversity. The establishment of these species pose a serious threat to the watershed as they can drastically alter the forest structure by outcompeting native plant species for light and nutrients and change soil and aquatic community composition (Hughes and Denslow 2005, Allison et al. 2006, Atwood et al. 2010, Global Invasive Species Database 2020a, Global Invasive Species Database 2020b).

Management actions that increase the plant and structural diversity of a habitat can be beneficial for bat species as monotypic habitats can precipitate a decrease in foraging quality (Fenton 1997, Williams et al. 2006, Taki et al. 2010). The objective of the management goals and actions below are to restore structural diversity of habitat and prevent further deterioration over the next eight years.

**Invasive Plant Species Management Goals and Actions**

NPMPP will place primary focus on managing species identified as posing a significant risk for causing habitat alteration through the creation of monotypic stands, as these are most likely to have negative impacts to bat foraging and roosting habitat. KMWP has accumulated a significant geospatial dataset that documents invasive species occurrence within the PMA. Supplemental funding in Year 1 and Year 5 of the Habitat Management Plan will be used to provide periodic mapping updates of invasive species using sUAS platforms(drones) and other aerial imagery analysis techniques. This location information as supplemented by data collected during field deployments will be used to target invasive vegetation control measures. Goals and associated actions are:

- Statistically significant reduction in target invasive weed species cover within the PMA, which indicates that the reduction is not explainable by chance alone (and it can be inferred that it is due to the management actions).
    - Field crews will be deployed at least monthly to manage invasive vegetation within the PMA. Due to the remote location and regular use of helicopter for deployment, KMWP has found deployment of field crews of four to six staff to be the most effective use of resources.
        - Primary target species will be mule's foot fern, strawberry guava, manuka, Moluccan albizia, and cane ti, as well as any incipient arrivals determined to pose a similar threat.
        - Control methods will vary and will leverage new management techniques as they become available. Approaches are described in Table 2.
- Implement surveillance and response protocols, based on the control methods shown in Table 2, to monitor for and remove priority incipient invasive species as soon as possible following discovery.
    - Field crews are well-trained and knowledgeable with respect to invasive species. During each quarterly field visit and at any time when staff are regular traversing of access trails and fence lines, field crews will monitor for the arrival of incipient invasive plant species. The timeline for removal/treatment will vary greatly depending on 1) species 2) what time of year it is documented (e.g., weather can make access more difficult/unsafe and treatments less effective) 3) based on #1 and #2, when is the most effective treatment time (e.g., typically before flowering and fruiting but some species can be treated year-round)
- Avoid the spread of invasive plant species to the PMA or to other managed sites from the PMA.
    - Field crews will implement avoidance and minimization measures to avoid transport of invasive species seeds to the PMA or to other managed sites from the PMA, which includes cleaning mud/soil off of shoes, gear, clothing, and vehicles (see Section 5.3) and following the ROD guidelines (see Section 5.1.2).

### *5.1.2 Plant pathogens*

Early detection and management of infected trees is critical to stop the spread of ROD. As of April 2023, there were 12 locations with positive ROD detections on O'ahu; six on residential properties and six in forested, wildland areas (DOFAW 2023). One of these 12 locations is the PMA, where in 2020, ROD was identified in five ōhiʻa trees(University of Hawaiʻi 2023). Of the two *Ceratocystis* species responsible for causing ROD, only *C. huliohia* has been identified within the management area. Although *C. huliohia* is less aggressive than *C. lukuohia* (University of Hawaiʻi 2023), it still poses a serious threat. The objective of the ROD management goal is to minimize the spread and impact of ROD within the PMA over the next eight years.

**ROD Management Goals and Actions**

Management actions will aim to identify and regress the spread of ROD while stopping further introductions of the pathogen throughout the PMA. Best use sampling practices are periodically updated by the University of Hawaiʻi College of Tropical Agriculture and Human Resources (CTAHR: ROD Sampling) and will be implemented as suggested. Goals and associated actions are:

- Identify and record trees suspected to be infected with *Ceratocystis* fungus. Observations will occur incidentally during implementation of management activities in PMA.
    - Field crews will be trained in the identification of trees suspected to be infected by ROD.
    - Suspected trees will be reported and, if appropriate, tested based on current guidance.
    - Where suspected or confirmed ROD is present, these areas will be avoided to the extent possible to minimize physical damage from staff and vehicles.
- Stop further introductions of ROD pathogen into the PMA.
    - All staff working in the PMA will be trained on proper procedures to minimize the risk of spreading ROD.
    - If not already established, an information sign will be set up at the entrance of the Poamoho Trail to educate trail users of the risk of ROD and necessary steps to stop it spread.
    - The information sign will be accompanied by a boot cleaning station.
    - Vehicles the travel off-road is areas where suspected or confirmed ROD is present, will wash the tires and undercarriage with detergent to remove all soil and mud prior to entering uninfected areas.

### *5.1.3 Feral ungulates*

Removal and exclusion of feral ungulates through fencing is a common and effective tool for managing invasion and disturbance to critical habitats and is an essential first step in habitat conservation and restoration. Ungulate removal is also critical in minimizing the impact of ROD.

Fence construction and removal of ungulates in the PMA was completed by KMWP, Oʻahu Army Natural Resources Program, and DLNR in 2016. However, continued financial support is required to ensure the integrity of the fence-line and exclusion of ungulates from the area. The objective of the feral ungulate management goal is to exclude pigs from the PMA and avoid associated potential impacts.

**Feral Ungulate Management Goals and Actions**

Currently feral pigs are the only ungulate of concern for the PMA. The following is an outline of goals and strategies to ensure the exclusion of feral ungulates from the PMA over the next eight years. Goals and associated actions are:

- Maintain fence integrity

  - Visual inspection of the entire fence-line will be conducted quarterly throughout the 8-year implementation of the Management Plan to ensure the integrity of the exclosure.

  - Additional fence inspections will be conducted following storm events along with increased surveillance for potential incursion if a breach in the fence is observed.
  - Repair of any holes or fasteners and replacement of panels or posts will be conducted as needed to maintain the integrity of the exclosure.
- Maintain feral pig exclusion from the PMA
  - Passive trapping and monitoring methods and visually check monitoring locations quarterly. Conduct opportunistic monitoring for pig sign in conjunction with weed removal and other management efforts.
  - Active hunting and passive trapping with snares, and increased monitoring will be implemented following identification of pig activity within the PMA.

## 5.2 Roles and Responsibilities

The division of responsibilities shown in Table 3 is based on communication with NPMPP that they will contract with KMWP to conduct fieldwork with oversight from Tetra Tech.

**Table 3. Anticipated Responsibilities by Entity**

| Tetra Tech | KMWP | NPMPP |
|---|---|---|
| Implementation management | Responsible for all threat management actions | Coordination with Tetra Tech and KMWP |
| Lead initial monitoring plot establishment in Year 1 | Responsible for all evaluative monitoring | Review annual reports |
| Lead initial acoustic detector and insect prey trap set up in Year 1 | Initial monitoring plot establishment assistance in Year 1 | Review of adaptive management actions, if needed |
| Training on implementation protocols | Assist with initial acoustic detectors and insect prey traps set up in Year 1 | |
| Quarterly check-in site visits during Year 1 to ensure that implementation is proceeding as intended, perform troubleshooting as needed | Lead quarterly bat prey monitoring and yearly vegetation monitoring in Years 1, 3, 5, and 8 | |
| Author annual report | Provide quarterly data summary for annual reporting | |
| Provide desktop and field support as needed for adaptive management | Complete adaptive management responses | |

## 5.3 Best Management Practices

Management staff will implement the best management practices below to prevent the introduction and spread of alien plants,  animals, insects, and forest pathogens within the PMA. Risk will be minimized by regular and thorough cleaning of field gear between deployments and limiting deployments to smaller areas within the PMA. When moving between different parts of the PMA is required in a single deployment, especially if moving from heavily infested areas to more native areas, new field gear will be used to minimize the risk of spreading invasive species

**Footwear - Daily**

- Spray down boots or tabis with hose removing excess mud and debris from tread, spikes, laces, and tongue as well as between the toes of tabis
- Scrub outside of boots or tabis with stiff brush to remove finer particles focusing on tread of boot and tabis as well as inner Velcro of tabis
- Spray boots or tabis again to rinse off last of debris as well as spray out inside of footwear
- Repeat if necessary if lingering mud or seeds remain
- Hang to dry and spray with 70 percent isopropyl alcohol

**Field Tools - Daily**

- Spray heads and body or handle of tools with hose to remove accumulated mud and plant material
- Scrub head until clean
- Spray down once more to rinse
- Hand tools and chainsaws shall be wiped down with 70 percent isopropyl alcohol. The chain shall be removed and soaked in 70 percent isopropyl alcohol for ten minutes.

**Backpacks and Clothing – No schedule**

- Remove everything from inside of backpack and any side pockets
- Hang from secure location and spray inside and outside of pack with hose making sure to spray out any tucks and folds in the backpack material
- Scrub areas with seams with stiff brush
- Spray with hose once more to rinse
- Clothes will be cleaned, washed, and dried in a dryer.

**Trucks – Weekly (or when moving from heavily infested areas to less infested areas)**

- Wash exterior of trucks with soap and water
- Spray undercarriage with high pressure hose to remove accumulation of mud and debris
- Remove any floor mats and wash with soap and water
- Vacuum out interior of trucks

# 6.0 Evaluative Monitoring

The monitoring plan is designed to monitor changes in vegetation, bat prey, and bat acoustic activity within the PMA during the period of performance (8 years) and provide periodic (Years 1, 3, 5, and 8) measurable results that can be used to identify successful mitigation or provide information to suggest that adaptive management is required to meet the Habitat Management Plan's measures of success (Table 4). Additional monitoring components discussed above (sections 4.2.1 – 4.2.3) include monitoring for incipient invasive species, ROD, fence integrity, and feral ungulate intrusion to the PMA. However, although these measures are considered beneficial and will contribute to the overall success of the project, they will not directly show changes at the PMA associated with improvements to bat foraging habitat, bat prey, nor bat use. Baseline conditions will be based on monitoring during Year 1 of this Habitat Management Plan (Section 6.1).

**Table 4. Anticipated Project Implementation Timeline**

| Time Frame | Mitigation Year | Description of Actions |
| --- | --- | --- |
| 2024 | Year 1 | • Initiation of management actions<br>• Baseline vegetation monitoring (April to June)<br>• Baseline bat prey monitoring (quarterly)<br>• Baseline bat acoustic activity monitoring (nightly)<br>• Data analysis (3-month period immediately following conclusion of evaluative monitoring annual cycle) |
| 2025 | Year 2 | • Implementation of management actions<br>• Annual report (by June 1) |
| 2026 | Year 3 | • Implementation of management actions<br>• Vegetation monitoring (April to June)<br>• Bat prey monitoring (quarterly)<br>• Bat acoustic activity monitoring (nightly)<br>• Data analysis (3-month period immediately following conclusion of evaluative monitoring annual cycle)<br>• Annual report (by June 1) |
| 2027 | Year 4 | • Implementation of management actions<br>• Annual report (by June 1) |
| 2028 | Year 5 | • Implementation of management actions<br>• Vegetation monitoring (April to June)<br>• Bat prey monitoring (quarterly)<br>• Bat acoustic activity monitoring (nightly)<br>• Data analysis (3-month period immediately following conclusion of evaluative monitoring annual cycle)<br>• Adaptive management (as needed, based on monitoring data)<br>• Annual report (by June 1) |
| 2029 | Year 6 | • Implementation of management actions<br>• Vegetation bat prey, and bat acoustic activity monitoring (based on Year 5 results)[1]<br>• Data analysis (3-month period immediately following conclusion of evaluative monitoring annual cycle)[2]<br>• Adaptive management (continues as needed, based on Year 5 monitoring data)<br>• Annual report (by June 1) |

| Time Frame | Mitigation Year | Description of Actions |
|---|---|---|
| 2030 | Year 7 | • Implementation of management actions<br>• Vegetation bat prey, and bat acoustic activity monitoring (based on Year 5 results)[1]<br>• Data analysis (3-month period immediately following conclusion of evaluative monitoring annual cycle)[2]<br>• Adaptive management (continues as needed, based on Year 5 monitoring data)<br>• Annual report (by June 1) |
| 2031 | Year 8 | • Implementation of management actions<br>• Vegetation monitoring (April to June)<br>• Bat prey monitoring (quarterly)<br>• Bat acoustic activity monitoring (nightly)<br>• Data analysis (3-month period immediately following conclusion of evaluative monitoring annual cycle)<br>• Annual report (by June 1) |
| 2032 | Post-Mitigation | • Final annual report (by June 1) |

[1] NPMPP will add monitoring in Years 6 and 7 if Year 5 bat acoustic activity has not increased (see Section 9.0)
[2] If adaptive management is required additional monitoring will be added in Year 6 and possibly Year 7.

## 6.1 Vegetation and bat prey monitoring

Bat prey and vegetation conditions will be tracked at 15 monitoring plots distributed semi-randomly, considering logistical factors and capturing a range of initial conditions relative to level of establishment of target invasive species in the monitoring plots.

### *6.1.1 Planned method*

Fifteen 0.5-hectare (20 meter x 25 meter) monitoring plots will be established within the PMA (Figure 3). Initial delineation of the monitoring plots will include the establishment of photo points at the plot's corners and the collection of baseline data including GPS location, invasive vegetation cover, slope, and elevation. Plots will be selected and categorized by the degree of invasive vegetation cover to evaluate its effect on arthropod abundance (Emery and Doran 2013). Five monitoring plots will contain no observed presence of mule's foot fern, strawberry guava, manuka, or Mollucan albizia (invasive species deemed likely to form large monotypic habitat altering stands), serving as an initial condition of "native forest." Another five monitoring plots will include areas where one of these invasive species are established but have not yet dominated the vegetation community, representing and initial condition of "established invasive species" (ground or canopy cover< 5 percent[2]). The last five plots will include areas where the selected invasive species is dominant within the vegetation community (ground or canopy cover > 30 percent[4]),

[4] Percentages are approximate values, subject to adjustment based on identification of ranges found within otherwise suitable monitoring plots. Choice of ground cover or canopy cover as measure of species

serving as an initial condition of "invasive species dominated." Plot locations meeting the habitat selection criteria above and safety and logistical requirements will be identified within randomly selected grid cells covering the PMA. Logistics, including implementation of practices to avoid spreading invasive plant species within the PMA, will require grouping of monitoring plots into clusters to allow monitoring of 3 – 4 individual plots per day. To ensure independence, monitoring plot locations will be at least 200 meters apart.

Arthropod sampling will occur in the monitoring plots four times a year in each monitoring year (Years 1, 3, 5, and 8) (Table 4). Timing of quarterly sampling will be consistent across all sampling years and align with bat reproductive periods as defined by Gorresen et al. (2013): lactation (mid-June to August), post-lactation (September to mid-December), pre-pregnancy (mid-December to March), and pregnancy (April to mid-June). Vegetation sampling will occur once annually each monitoring year in Years 1, 3, 5, and 8, during the peak blooming period for annual vegetation ( April to June). Photos will be taken at the established photo points for each plot, and sampling will include:

- Vegetation
    - Invasive plant species absolute percent cover
    - Plant species richness
- Arthropods
    - Diversity
    - Abundance (i.e., biomass)

### *6.1.2 Alternative method*

Should the planned monitoring plot layout prove impractical in the field due to terrain (e.g., plot size/shape not allowing for safe and practicable collection of data on a regular basis) or vegetation density (e.g., dense patches of uluhe which could be damaged through the regular collection of monitoring data), monitoring plots will be modified to be linear transects. Ultimately, all plots will be of the same type (linear or rectangular), including control plots proposed in the Research Plan (Tetra Tech 2024). The decision on which approach to use will be based on a preliminary site visit upon the approval of the Management Plan and Research Plan.

The alternative linear transect plots would be 100 meters long and allow for the same sampling and data collection protocols. In this case, all work would be performed from a flagged central transect line and sampling would be limited to 2.5 meters on either side of the transect line (5-meter survey buffer). Five photo points would be established along the transect path at regular intervals: 0, 20, 40, 60, and 80 meters.

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dominance is dependent on species. For example, strawberry guava stands only come to dominate ground cover through leaf litter, and this not common at the elevations associated with the PMA. In the vicinity of the PMA canopies dominated by strawberry guava often have associated understories dominated by Koster's curse (*Clidemia hirta*), a species deemed "beyond control" by management agencies. Mollucan albizia's dominance similarly exerts its influence at the canopy level, resulting in the transition of understory to bare earth or invasive groundcover species.

### 6.1.3 Vegetation monitoring

This section initially describes how the planned method (see Section 6.1.1) would be used to monitor vegetation in the PMA. A second section describes how that sampling approach would be adjusted if the alternative sampling plot approach (see Section 6.1.2) is used.

#### 6.1.3.1 Planned method

Monitoring plots will be subject to the same habitat management actions as the remainder of the habitat within the PMA. This differentiates these evaluative monitoring plots from the control plots identified in the Research Plan (Tetra Tech 2024), which occur outside the PMA, will not be actively managed, and which are likely to be impacted by feral ungulates (Figure 4).To measure invasive plant species absolute percent cover, the relative area covered by each invasive species will be estimated in ten 1-meter$^2$ quadrats located around the boundary of each plot (approximately 9 meters apart; Figure 3). Bonham (2013) and KMWP staff were consulted to determine if the sampling design would be suitable for quantifying invasive species absolute percent cover. Given the relative abundance of mule's foot fern in the PMA and adjacent area, Tetra Tech determined that the sampling design would adequately differentiate and track changes in amounts of invasive species cover over time. Invasive plant species absolute percent cover will be averaged for each of the individual 15 plots based on the species cover in each of the ten quadrats within each plot.

To measure plant species richness in each plot, all individual species (includes trees, shrubs, grasses, and ferns) will be counted in ten 1 meter$^2$ quadrats located around the boundary of each plot (same plots used to estimate invasive plant species absolute percent cover, above) (e.g., Keeley and Fotheringham 2005, Young and Johnstone 2011). Plant species richness values from each quadrat will be averaged for each of the 15 plots. A supplemental search will be conducted in each plot, following invasive plant species and plant species richness data collection, to identify any plant species that did not occur within the quadrats and will be added to species richness measurements for each plot. The supplemental search will be a 15-minute to one-hour effort providing meandering survey coverage over the remainder of the plot.[5] This will ensure a consistent level of effort among plots.

#### 6.1.3.2 Alternative method

Under the linear transect monitoring approach sampling quadrats would be positioned adjacent to, but outside, the foot trail forming the transect and located at: 5, 15, 25, 35, 45, 55, 65, 75, 85, and 95 meters from the transect starting point. Sampling outside of the quadrats for other plant species would occur within the 5-meter survey buffer along the 100-meter long transect. In all other respects, vegetation sampling protocols would match those described in section 6.1.3.1.

[5] If no new species are added and coverage of the entire plot is complete within 15 minutes, the supplemental search will end. If new species are added, additional time will be added up to one hour or until the entire plot has been surveyed.

### *6.1.4 Bat prey monitoring*

This section initially describes how the planned method (see Section 6.1.1) would be used to monitor bat prey in the PMA. A second section describes how that sampling approach would be adjusted if the alternative sampling plot approach (see Section 6.1.2) is used.

#### *6.1.4.1 Planned method*

Arthropods will be sampled in each plot using two methods: sweep nets or a vacuum aspirator and a light trap or malaise trap. Each sampling method is best suited for certain taxa, and the use of multiple sampling methods may give more complete results than the use of a single method (McCravy 2018). Light traps are an extremely common and efficient trapping method, attracting insects towards the light where they are funneled into a collection container. Malaise traps are large tent like structures made of netting that funnel insects into a common area (Montgomery et al. 2021) Both light traps and malaise traps target flying insects, such flies (Diptera), wasps, flying ants, bees (Hymenoptera), true bugs (Hemiptera), moths (Lepidoptera) (Montgomery et al. 2021). The malaise trap would be modified to include a collection reservoir (e.g., a pan with collecting liquid) at the bottom as well as the top to ensure beetles are collected (DOFAW pers. comm May 25, 2023). Spatial placement is extremely important for both of these trap types given that light traps are only effective at a distance of less than 30 meters (Truxa and Fiedler 2012) and malaise traps must be within the flight path of the insect (Montgomery et al. 2021).

Vacuum aspirators and sweep nets collect insects directly from vegetation, capturing both flying and non-flying insects, and can also be used to collect epigeic (i.e., live on the soil surface) arthropods (McCravy 2018). Both sweep nets and vacuum aspirators have been found to result in similar species richness, however the mean size of invertebrate biomass was greater for sweep netting than vacuum sampling. Vacuum sampling was more effective at collecting small (less than 5 cm) invertebrates, whereas sweep netting captured large (greater than 5 cm) Orthoptera and Lepidoptera larvae at higher rates (Doxon et al. 2010).

Collection using sweep nets or vacuum aspirators will be conducted along five parallel 20 meter transects, approximately 1 meter wide, spaced 5 meters apart (Figure 3) over the course of one day. Malaise traps or light traps will be placed at the center of each of the plots (Figure 3). Malaise traps would operate for one to two weeks per quarterly sampling period and light traps would operate two to three nights per quarterly sampling period. All samples collected will be combined for each plot. Arthropods collected during each sampling period with a body length ≥ 5 millimeters will be sorted to order, size, and oven-dried for 48 hours at 65°C (Gorresen et al. 2018). Size classifications will include ≥ 5 to 10 millimeters, >10 to 20 millimeters, and > 20 millimeters. Biomass was chosen as it has shown to be a better response variable when investigating trophic interactions and can provide a more accurate picture of the processes driving changes in community structure (Saint Germain et al. 2007).

#### *6.1.4.2 Alternative method*

Under the linear transect monitoring approach sweep net or vacuum aspirator sampling would occur along the entire 100-meter long transect. The Malaise trap or light trap would be positioned at approximately the mid-point (50 meters) of the 100-meter long transect. In all other respects, insect sampling protocols would match those described in section 6.1.4.1.

## 6.2 Bat acoustic activity monitoring

The goal of bat acoustic activity monitoring is to quantify increases in bat acoustic activity at the site as a function of changes to foraging and roosting activity in response to the management actions. To measure changes, NPMPP will deploy 15 acoustic monitors within the PMA (one per plot). Nightly monitoring, beginning 1-hour prior to sunset and ending 1-hour after sunrise, will be conducted for a 12-month period in Years 1, 3, 5, and 8. During monitoring years, acoustic monitoring data will be downloaded at least quarterly.

Acoustic monitoring will be conducted using Song Meter SM4BAT-FS (SM4) ultrasonic recorders equipped with high frequency microphones (SMM-U2; Wildlife Acoustics, Inc., Maynard, MA). Each of the SM4 acoustic monitors will be placed within 30 meters of one of the monitoring plots (Section 6.1). The specific location will be identified to maximize the probability of collecting bat detections. These will remain in a constant location during all the monitoring years, including the baseline year. The distribution density of all 15 SM4 acoustic monitors is approximately 1 detector/0.6 kilometers$^2$.

The following bat use metrics will be reported:

- Detection rate = total nights with bat calls/total active detector-nights (primary measure);
- Number of nightly call files;
- Number of echolocation pulses;
- Type of call (i.e., passive or active search call, and feeding buzz);
- Foraging duration; and
- Timing of nightly activity

# 7.0 Analysis

For this Habitat Management Plan, analyses target the evaluation of changes of invasive plant species, arthropod communities, and bat acoustic activity within the PMA from baseline conditions. The Research Plan (Tetra Tech 2024) integrates and compares the changes in invasive plant and arthropod communities to help understand how areas where management levels are reduced and feral ungulates evolve over time.

An Analysis of Covariance (ANCOVA) will be conducted on data from the 15 plots to compare the effects of that habitat degradation, through invasive species, on arthropod biomass and richness. Year and initial status will be the main effects while invasive plant species cover, plant species richness, slope, and elevation will be covariates. A PERMANOVA (Anderson 2001) will be used to compare arthropod and invasive plant community composition among site initial conditions over time. Canonical analyses of principal coordinates (CAP; Anderson and Willis 2003) will be used to visualize how arthropod and invasive plant communities shifted.

Bat use metrics will be summarized during evaluative years and compared to baseline data to evaluate changes in the use metrics over time. Depending on the patterns of observed use, bat use metrics may be evaluated seasonally to highlight changes correlated with management activities.

# 8.0 Success Criteria

Baseline measures for success criteria will be established based on results in Year 1 of this Habitat Management Plan to ensure that the effects measured are changes that can reasonably attributed to the mitigation actions. Based on consultation with USFWS and DOFAW, successful implementation of the management portion of the bat mitigation plan will be demonstrated through performance of habitat management actions that improve the environment for bats and demonstration that these changes are correlated with a statistically significant increase in bat acoustic activity. This is consistent with the Hawaiian hoary bat guidance document (DOFAW 2021), which states that core use area "habitat restoration that enhances or increases forested and foraging areas for bats is an optimum mitigation approach".

Monitoring population trends is challenging as standard methods for estimating population size or densities across the landscape are not yet feasible (Frick 2013, Gorresen et al. 2018, Cornman 2021, Kotila 2023). Instead, changes in the magnitude of activity rather than abundance are frequently used as a proxy for population trends (Sugai et al. 2019). Although bat acoustic activity cannot provide direct counts of individual bats[6], over time it does allow us to detect changes in how bats are using an area. Further assessment of the behavioral states from vocalizations identified within recorded acoustic activity can provide additional context on habitat use and insight into a populations' response to conservation actions (Teixeira et al. 2019).

The suite of metrics proposed for monitoring will provide sufficient data to detect changes in seasonality of use and intensity of use. When combined with knowledge on the timing of key life-history stages, vocal behaviors from acoustic data can be used to identify important habitats for reproductive success. Examining the spatial and temporal trends in vocal behaviors through acoustic monitoring can provide a means to assess habitat quality, evaluate the effectiveness of conservation actions, and identify factors in the environment that could be adaptively managed (Teixeira et al. 2019). Therefore, a statistically significant increase in bat acoustic activity (i.e., p-value $< 0.05$) indicates that the observed change or difference in bat acoustic activity pre- and post-mitigation is unlikely to have occurred due to random chance. As a result, it provides confidence that the observed increase is a real and meaningful effect.

[6] For example, it is not possible to know if 10 bat passes represent 10 bats or one bat passing 10 times (Frick 2013).

The success criteria that follow provide a lens that connect the dots between the mitigation actions and the benefits to Hawaiian hoary bats. Specifically, habitat management actions, are expected to change the plant communities in the PMA to increase plant richness and reduce invasive species. This change in forest condition is expected to increase the diversity or abundance of bat prey. Changes in habitat quality, including the amount of bat prey, is expected to increase bat acoustic activity. Enhancement of 1,307 acres of Hawaiian hoary bat habitat in the PMA over this period in combination with the associated $100,000 Research Plan (Tetra Tech 2024) was determined in the Project HCP as sufficient to mitigate for the potential take of 34 bats in Tier 1 (see Tetra Tech [2016] for details).

**Success Criteria:**

All reported changes below will include 95 percent confidence intervals and significance at an alpha value of 0.05.

1. Statistically significant increase in plant species richness over baseline by Year 8;
2. Statistically significant reduction in invasive plant species absolute percent cover over baseline by Year 8;
3. Statistically significant increase in arthropod abundance or richness increase over baseline by Year 8; and
4. Statistically significant increase in bat acoustic activity (one or both of the primary measures) indicating bat activity has increased (duration or level of activity) over the 8-year implementation period for this Management Plan.

# 9.0 Adaptive Management

Adaptive management will be triggered when the monitoring data suggest the mitigation project is not on track to meet the success criteria (Table 4). NPMPP will analyze data in years 1 (baseline), 3, 5, and 8 to track progress towards meeting goals. If plant species richness and arthropod abundance or richness have not resulted in a statistically significant increase over baseline in Year 5, adaptive management would be triggered. Similarly, if bat acoustic activity has not shown an increase in duration or level of activity over baseline by Year 5 (this increase does not need to be significant), adaptive management would be triggered. Adaptive management actions will be responsive to the observed results, and would be developed in consultation with USFWS, DOFAW, and KMWP. Any identified adaptive management actions would be approved by USFWS and DOFAW prior to implementation.

If by Year 5 plant species richness or arthropod abundance or richness have not resulted in a statistically significant increase in "established invasive species" and "invasive species dominated" plots, NPMPP will initiate supplemental out-planting of native species within the PMA to promote recovery of areas impacted by invasive plant species (Table 5). Out-planting stock will be selected based on identified areas requiring supplemental planting and sourced in consultation with KMWP, DOFAW Oʻahu Branch, and DOFAW and USFWS HCP staff to ensure the plant stock is appropriate for planting in the area.

If by Year 5 bat acoustic activity has not shown an increase in a primary bat acoustic activity metric (either in duration or in level of activity; this increase does not need to be significant), NPMPP will either increase the intensity of the management, particularly with respect to invasive species, in the PMA or identify additional target areas for increased management (Table 3). This could include additional focus on larger areas with significant on-going invasive species impacts or areas of potential focal bat use, such as water sources like the pond near the Koʻolau Mountains ridge summit. In addition, if bat acoustic activity has not shown an increase by Year 5, this will trigger additional monitoring in Year 6. If bat acoustic activity in Year 5 shows an increase but that increase is not statistically significant (i.e., the Management Plan is on track to meeting the success criteria), additional management actions are not triggered but monitoring is required in Year 6.

If by Year 6, bat acoustic activity has not shown a statistically significant increase in bat acoustic activity NPMPP will conduct additional adaptive management actions (Table 3) and add monitoring in Year 7 to continue to track progress towards a statistically significant increase in bat acoustic activity as required by the success criteria. If by Year 6, bat acoustic activity shows a statistically significant increase in bat acoustic activity, the Management Plan is on a track to meeting the final success criteria and NPMPP can forgo Year 7 monitoring and adaptive management.

**Table 5. Adaptive Management Triggers and Responses**

| Monitoring Year | Plant Species Richness | Arthropods | Bat Acoustic Activity | Potential Adaptive Management Response |
|---|---|---|---|---|
| Year 1 | Baseline Monitoring | | | |
| Year 3 | No increase in plant species richness within established invasive species and invasive species dominated plots compared to baseline | No arthropod increase within established invasive species and invasive species dominated plots compared to baseline | No trigger, as this is expected to be a lagging indicator | • Identify additional target areas for increased management<br>• Supplemental out-planting of native species<br>• Remove non-priority weed species to increase extent and quality of native habitat<br>• Identify additional target areas for increased management<br>• Increase the intensity of management throughout the PMA |
| Year 5 | No statistically significant increase within established invasive species and | No statistically significant increase within established invasive species and | No increase in a primary bat activity metric (either duration or level of | • Supplemental out-planting of native species |

| Monitoring Year | Plant Species Richness | Arthropods | Bat Acoustic Activity | Potential Adaptive Management Response |
|---|---|---|---|---|
| | invasive species dominated plots compared to baseline | invasive species dominated plots compared to baseline | activity) compared to baseline; this increase does not need to be significant (would trigger adaptive monitoring in Year 6) | • Remove non-priority weed species to increase extent and quality of native habitat<br>• Identify additional target areas for increased management<br>• Increase the intensity of management throughout the PMA |
| Year 6[1] | No statistically significant increase in established invasive species and invasive species dominated plots compared to baseline | No statistically significant increase in established invasive species and invasive species dominated plots compared to baseline | No statistically significant increase in a primary bat activity metric (either duration or level of activity) compared to baseline(would trigger adaptive management and monitoring in Year 7) | • Supplemental out-planting of native species<br>• Remove non-priority weed species to increase extent and quality of native habitat<br>• Identify additional target areas for increased management<br>• Increase the intensity of management throughout the PMA |
| Year 7[2] | No statistically significant increase in established invasive species and invasive species dominated plots compared to baseline | No statistically significant increase in established invasive species and invasive species dominated plots compared to baseline | No statistically significant increase in a primary bat activity metric (either duration or level of activity) compared to baseline | • Supplemental out-planting of native species<br>• Remove non-priority weed species to increase extent and quality of native habitat<br>• Identify additional target areas for increased management<br>• Increase the intensity of management throughout the PMA |
| Year 8 | Success criteria are not met | | | • Extend management duration |

| Monitoring Year | Plant Species Richness | Arthropods | Bat Acoustic Activity | Potential Adaptive Management Response |
|---|---|---|---|---|
| | | | | • Identify additional target areas for increased management |

[1]Only applicable if Year 5 success criteria are not met.
[1]Only applicable if Year 6 success criteria are not met.

# 10.0 Budget

The estimated annual budget for habitat management and monitoring is shown in Table 6.

**Table 6. Estimated Annual Budget for Habitat Management and Monitoring**

| Year | Estimated Management Budget (2024 Dollars) | Estimated Monitoring Budget (2024 Dollars)[1] | Estimated Total Budget (2024 Dollars) |
|---|---|---|---|
| Year 1 | $228,314 | $276,321 | $504,635 |
| Year 2 | $228,314 | -- | $228,314 |
| Year 3 | $228,314 | $144,130 | $372,444 |
| Year 4 | $228,314 | -- | $228,314 |
| Year 5 | $228,314 | $144,130 | $372,444 |
| Year 6 | $228,314 | -- | $228,314 |
| Year 7 | $228,314 | -- | $228,314 |
| Year 8 | $228,314 | $144,130 | $372,444 |
| **Total** | **$1,826,512** | **$708,711** | **$2,535,223** |

[1]Amount includes monitoring under the management and research plans combined.

A detailed breakdown of the estimated annual budget for habitat management is shown in Table 7.

**Table 7. KMWP Estimated Annual Budget for Habitat Management**

| Description | Total |
|---|---|
| Salaries and Fringe Benefits (2 FTE equivalent + 1 partial FTE [coordination] | **$129,576** |
| Helicopter (40 days) | $46,410 |
| Materials and supplies | $8,700 |
| Vehicle use, fuel, maintenance | $5,000 |
| Training | $1,300 |
| Travel | $4,200 |

| Description | Total |
|---|---|
| Utilities | $1,500 |
| PCSU administration | $10,872 |
| Overhead | $20,756 |
| **Subtotal (materials, transport, and administration)** | **$98,738** |
| **Grand Total** | **$228,314** |

A detailed breakdown of the estimated combined budget for habitat monitoring at the PMA and the control site is shown in Table 8. Based on varying levels of effort required to conduct evaluative and research monitoring, Tetra Tech estimates assumes three quarters of staffing, materials, reporting, and analysis costs are attributable to the Management Plan and one quarter of the costs are attributable to the Research Plan (Tetra Tech 2024). This cost distribution accounts for additional analysis and field work associated with bat acoustic monitoring work in the PMA and the lower number of control plots. This categorization results in an estimate of $177,178 in research funding, exceeding the $100,000 in research funding required by the Project HCP for Tier 1 bat mitigation. Year 1 costs are significantly greater due to one-time only labor costs associated with set up of the monitoring plots and the purchase of monitoring equipment.

**Table 8. Estimated Budget for Habitat Monitoring, Analysis, and Reporting**

| Description | Entity | Year 1 Total[1] | Years 3, 5, 8 Total (Annual)[1] |
|---|---|---|---|
| Salaries and Fringe Benefits (Intermittent) | KMWP | $49,200 | $43,200 |
| Salaries and Fringe Benefits (3 Partial FTE) | Tetra Tech | $111,381 | $33,851 |
| **Subtotal (staffing)** | | **$160,581** | **$77,051** |
| Helicopter (41 days Year 1/36 days Years 3, 5, 8) | KMWP | $47,338 | $36,067 |
| Bat acoustic detectors (15) | Tetra Tech | $22,500 | $3,000 |
| Insect traps (15) | Tetra Tech | $1,500 | -- |
| Other materials and supplies | Tetra Tech & KMWP | $1,500 | $500 |
| Vehicle use, fuel, maintenance | KMWP | $5,000 | $5,000 |
| Training | KMWP | $1,300 | $1,300 |
| Travel | Tetra Tech & KMWP | $10,538 | $3,360 |
| Utilities | KMWP | $1,500 | $1,500 |
| PCSU administration | KMWP | $7,261 | $5,073 |
| Overhead | KMWP | $11,546 | $9,600 |
| **Subtotal (materials, transport, and administration)** | | **$109,983** | **$65,400** |
| Hawaiʻi GET | Tetra Tech | $5,757 | $1,679 |
| **Grand Total** | | **$276,321** | **$144,130** |

| Description | Entity | Year 1 Total[1] | Years 3, 5, 8 Total (Annual)[1] |
|---|---|---|---|
| [1] Amount includes management and research plan costs combined | | | |

# 11.0 Reporting

Annual reports will be submitted to the cooperating agencies and stakeholders that summarize the results of restoration activities, preliminary analysis results, and adaptive management approaches to habitat management and restoration. A final report will be submitted upon the successful implementation of the mitigation program described here, including having achieved the success criteria described in Section 8.

# 12.0 References

Allison, S.D., C. Nielsen, and R.F. Hughes. 2006. Elevated enzyme activities in soils under the invasive nitrogen-fixing tree *Falcataria moluccana*. Soil Biol. Biochem., 38, 1537–1544.

Anderson M.J. 2001. A new method for non-parametric multivariate analysis of variance. Aust. Ecol.: 26, 32–46.

Anderson, M.J. and T.J. Willis. 2003. Canonical analysis of principal coordinates: a useful method of constrained ordination for ecology. Ecology: 84(2), pp. 511–525.

Atwood, T.B., T.N. Wiegner, J.P. Turner, and R.A. MacKenzie. 2010. Potential effects of an invasive nitrogen-fixing tree on a Hawaiian stream food web. Pacific Science, vol. 64, no. 3:367–379.

Auwahi Wind. 2023. Auwahi Wind Farm habitat conservation plan FY 2023 Annual Report. Avaialable at: https://dlnr.hawaii.gov/wildlife/files/2024/01/Auwahi-Wind-Annual-Report-2023-Compiled.pdf

Barnes, I., A. Fourie, M.J. Wingfield, T.C. Harrington, D.L. McNew, L.S. Sugiyama, B.C. Luiz, W.P. Heller, and L.M. Keith. 2018. New *Ceratocystis* species associated with rapid death of *Metrosideros polymorpha* in Hawaiʻi. Persoonia – Molecular Phylogeny and Evolution of Fungi Vol. 40 (June 2018), pp,. 154–181.

Belwood, J.J. and J.H. Fullard, 1984. Echolocation and foraging behaviour in the Hawaiian hoary bat, *Lasiurus cinereus semotus*. Canadian Journal of Zoology, 62(11), 2113–2120.

Bonaccorso, F.J., C.M. Todd, A.C. Miles, and P.M. Gorresen. 2015. Foraging range movements of the endangered Hawaiian hoary bat, *Lasiurus cinereus semotus* (Chiroptera: Vespertilionidae). Journal of Mammalogy, 96(1), 64–71.

Bonham, C.D. 2013. Measurements for terrestrial vegetation, 2nd Edition. Wiley-Blackwell 260 pp.

Busby P.E., P. Vitousek, and R. Dirzo. 2010. Prevalence of tree regeneration by sprouting and seeding along a rainfall gradient in Hawai ʻi. Biotropica 42:80–86.

Christenhusz, M.J.M. and T.K. Toivonen. 2008. Giants invading the tropics: the oriental vessel fern, *Angiopteris evecta* (Marattiaceae). Biological Invasions 10, 1215–1228. https://doi.org/10.1007/s10530-007-9197-7

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(4):463–471.

Cole, R. and C. Litton. 2014. Vegetation response to removal of non-native feral pigs from Hawaiian tropical montane wet forest. Biological Invasions. 16. 10.1007/s10530-013-0508-x.

Davidson, L.N. 2020. Assessing ʻŌpeʻapeʻa (Hawaiian Hoary Bat, *Lasiurus semotus*) Habitat Use and Occupancy in the Helemano Wilderness Area, Central Oʻahu. Capstone Project for the degree of Master of Environmental Management. Department of Natural Resources and Environmental Management, University of Hawaiʻi at Mānoa. Available at: https://scholarspace.manoa.hawaii.edu/items/b10c8b9a-d26d-4504-893a-3ca70cc66ffd.

Dawson, J.W. and L. Stemmermann, L. 1990. *Metrosideros* Banks ex Gaertn. In Manual of the flowering plants of Hawaii, vol. 1 (eds W.L. Wagner, D.R. Herbst and S.H. Sohmer), pp. 964–970. Honolulu, HI: University of Hawaiʻi Press.

DLNR (Hawaiʻi Department of Land and Natural Resources). 2015. Hawaiʻi's State Wildlife Action Plan. Prepared by H. T. Harvey and Associates, Honolulu, Hawaiʻi.

DLNR. 2018. Blog post: 12/21/18-Aggressive rapid ʻōhiʻa death fungus found on Kauaʻi. Available at: https://dlnr.hawaii.gov/blog/2018/12/21/nr18-244/

DOFAW (Hawaiʻi Division of Forestry and Wildlife). Endangered Species Recovery Committee Hawaiian Hoary Bat Guidance Document. December 2015. Available at: https://dlnr.hawaii.gov/wildlife/files/2016/06/Bat-White-Paper-Guidance_and-Impl-Plan.pdf

DOFAW 2023. Rapid Ohia Death Detected for First Time in Waianae Mountains. News Article. April 10. https://dlnr.hawaii.gov/blog/2023/04/10/nr23-65/. Accessed September 18, 2023.

DOFAW pers. comm. 2023. Comment in draft habitat management plan for the Poamoho Management Area. May 25, 2023.

Doxon, E. D., C.A. Davis, and S.D. Fuhlendorf. 2010. Comparison of two methods for sampling invertebrates: vacuum and sweep-net sampling. Journal of Field Ornithology, vol. 82, no. 1, 2011, pp. 60–67. JSTOR, http://www.jstor.org/stable/23011125. Accessed 29 Aug. 2023.

Emery, S.M. and P.J. Doran. 2013. Presence and management of the invasive plant *Gypsophila paniculata* (baby's breath) on sand dunes alters arthropod abundance and community structure. Biological Conservation. Volume 161. Pages 174–181.

Fenton, M.B., L. Acharya, D. Audet, M.B.C. Hickey, C. Merriman, M.K. Obrist, D.M. Syme, and B. Adkins. 1992. Phyllostomid bats (Chiroptera: Phyllostomidae) as indicators of habitat disruption in the Neotropics. *Biotropica*, pp.440–446.

Fenton, M.B. 1997. Science and the conservation of bats. Journal of mammalogy, *78*(1), pp.1–14.

Fortini, L.B., L.R. Kaiser, L.M. Keith, J. Price, R.F. Hughes, J.D. Jacobi, and J.B. Friday. 2019. The evolving threat of rapid ʻōhiʻa death (ROD) to Hawaiʻi's native ecosystems and rare plant species. Forest Ecology and Management. 448: 376–385. https://doi.org/10.1016/j.foreco.2019.06.025.

Friday, J.B. and D. A. Herbert. 2006. *Metrosideros polymorpha* (ʻōhiʻa lehua). Species Profiles for Pacific Island Agroforestry, pp. 465-490 in: C. R. Elevitch (ed.), Traditional trees of Pacific Islands: their culture, environment, and use. Permanent Agriculture Resources, Hōlualoa, HI. Online: http://www.agroforestry.net/tti/Metrosideros-ohia.pdf.

Frick, W.F., 2013. Acoustic Monitoring of Bats, Considerations of Options for Long-Term Monitoring. THERYA. Vol. 4(1):69-78. DOI: 10.12933/therya-13-109

Funk, E. 1987. Spontaneous spread of *Angiopteris evicta* (Marattiales) in the central Koʻolau Mountains, Oʻahu, Hawaiʻi. Hawaiian Botanical Society Newsletter 26, 58 – 59.

Gorresen, P.M., F.J. Bonaccorso, C.A. Pinzari, C.M. Todd, K. Montoya-Aiona, and K.W. Brinck. 2013. A five-year study of Hawaiian hoary bat (*Lasiurus cinereus semotus*) occupancy on the island of Hawaii. (No. HCSU-041). University of Hawaiʻi at Hilo.

Gorresen, P.M., P.M. Cryan, M.M. Huso, C.D. Hein, M. Schirmacher, J.H. Johnson, K. Montoya-Aiona, K.W. Brinck, and F. Bonaccorso. 2015. Behavior of the Hawaiian hoary bat (*Lasiurus cinereus semotus*) at wind turbines and its distribution across the North Koʻolau Mountains, Oʻahu (No. HCSU-064). University of Hawaiʻi at Hilo.

Gorresen, P.M., K.W. Brinck, M.A. DeLisle, K. Montoya-Aiona, C.A. Pinzari, and F.J. Bonaccorso. 2018. Multi-state occupancy models of foraging habitat use by the Hawaiian hoary bat (*Lasiurus cinereus semotus*). *PloS one*, *13*(10), p.e0205150.

Global Invasive Species Database. 2020a. Species profile: *Psidium cattleianum*. http://www.iucngisd.org/gisd/speciesname/Psidium+cattleianum. Accessed on 10-11-2020.

Global Invasive Species Database. 2020b. Species profile: *Falcataria moluccana*. http://www.iucngisd.org/gisd/speciesname/Falcataria+moluccana. Accessed on 16-11-2020.

Gruner, D.S. 2004. Attenuation of top-down and bottom-up forces in a complex terrestrial community. Ecology Vol. 85(11): 3010–3022.

Haddad, N.M., D. Tilman, J. Haarstad, M. Ritchie, and J.M. Knops. 2001. Contrasting effects of plant richness and composition on insect communities: a field experiment. The American Naturalist, 158(1), pp.17–35.

H.T. Harvey (H.T. Harvey and Associates). 2020. Hawaiian hoary bat research, Maui—final report 2019. Project #3978-01. Prepared for TerraForm Power. Available at: https://dlnr.hawaii.gov/wildlife/files/2021/01/MauiBatsHTHFebruary2020.pdf

Hoeh, J.P.S., A.A. Aguirre, F.A Calderon, S.P. Casler, S.G. Ciarrachi, K.N. Courtot, K.M. Montoya-Aiona, C.A. Pinzari, and P.M. Gorresen. 2023. Seasonal and elevational differences by sex in capture rate of ʻŌpeʻapeʻa (*Lasiurus semotus*) on Hawaiʻi Island. Pacific Science 77(1), 1–26. https://www.muse.jhu.edu/article/906629.

Hughes, F.R. and J.S. Denslow. 2005. Invasion by a $N_2$-fixing tree alters function and structure in wet lowland forests of Hawaiʻi. Ecological Applications 15: 1615–1628.

Jacobs, D.S. 1996. Morphological divergence in an insular bat, *Lasiurus cinereus semotus*. Functional Ecology, 622–630.

Jacobs, D.S. 1999. The diet of the insectivorous Hawaiian hoary bat (*Lasiurus cinereus semotus*) in an open and a cluttered habitat. Canadian Journal of Zoology, 77(10), 1603–1608.

Jantzen, M.K. 2012. Bats and the landscape: The influence of edge effects and forest cover on bat activity. Electronic Thesis and Dissertation Repository. 439. https://ir.lib.uwo.ca/etd/439.

Kaiser, B., K. Burnett, and J. Roumasset. 2019. Control of Invasive Species: Lessons from *Miconia* in Hawaii. Available at: https://uhero.hawaii.edu/wp-content/uploads/2019/08/Miconia_JFE.pdf.

Kauaʻi Invasive Species Committee. 2015. Invasive impacts on erosion. Blog Post by Rachel Smith dated September 22, 2015. Available at: https://www.kauaiisc.org/invasive-impacts-on-erosion/.

Keeley, J.E. and C.J. Fotheringham. 2005. Plot shape effects on plant species diversity measurements. Journal of Vegetation Science 16(2): 249–256.

Keith, L.M., R.F. Hughes, L.S. Sugiyama, W.P. Heller, B.C. Bushe, and J.B. Friday. 2015. First report of *Ceratocystis* wilt on ʻōhiʻa. Plant Disease. http://dx.doi.org/10.1094/PDIS-12-14-1293-PDN.

KMWP (Koʻolau Mountains Watershed Partnership). 2002. Koʻolau Mountains Watershed Partnership Management Plan. Available at: http://hawp.org/_library/documents/koolau-mountains-wp/kmwpmp.pdf.

KMWP. 2016. Koʻolau Mountains Watershed Partnership action plan 2016–2017. Available at: https://koolauwatershed.org/wp-content/uploads/KMWP-2016-2017-Action-Plan.pdf.

Knops, J.M.H., D. Tilman, N.M. Haddad, S. Naeem, C.E. Mitchell, J. Haarstad, M.E. Ritchie, K.M. Howe, P.B. Reich, E. Siemann, and J. Groth. 1999. Effects of plant species richness on invasion dynamics, disease outbreaks, and insect abundances and diversity. Ecology Letters 2:286–293.

Lipscomb, D.J. 1989. Impacts of feral hogs on longleaf pine regeneration. Southern Journal of Applied Forestry 13:177–181.

Loope, L.L. 1998. Hawaiʻi and Pacific islands. In: M.J. Mac, P.A. Opler, C.E. Puckett Haecker, and P.D. Doran (Eds.), Status and Trends of the Nation's Biological Resources, vol. 2. U.S. Department of the Interior, U.S. Geological Survey, Reston, VA, pp. 747–774.

Loope, L. 2016. Guidance document for rapid ʻōhiʻa death: background for the 2017–2019 ROD strategic response plan. December 2016.

McCravy, K.W. 2018. A Review of Sampling and Monitoring Methods for Beneficial Arthropods in Agroecosystems. Insects. Volume 9(4), 170. https://doi.org/10.3390/insects9040170

Menard, T. 2003. Activity patterns of the Hawaiian hoary bat (*Lasiurus cinereus semotus*) in relation to reproductive time periods. M.Sc. thesis, University of Hawaiʻi at Manoa.

Mitchell, J., W. Dorney, R. Mayer, and J. McIlroy. 2007. Spatial and temporal patterns of feral pig diggings in rainforests of north Queensland. Wildlife Research 34:597–602.

Montgomery G.A., M.W. Belitz, R.P. Guralnick, and M.W. Tingley. 2021. Standards and best practices for monitoring and benchmarking insects. *Front. Ecol. Evol.* 8:579193. doi: 10.3389/fevo.2020.579193

Montoya-Aiona, K.M. 2020.Roosting ecology and behavior of the solitary and foliage-roosting Hawaiian hoary bat *(Lasiurus cinereus semotus)*. M.Sc. thesis, University of Hawaiʻi at Hilo.

Montoya-Aiona, K., P.M. Gorresen, K.N. Courtot, A. Aguirre, F. Calderon, S. Casler, S. Ciarrachi, J. Hoeh, J.L. Tupu, and T. Zinn. 2023. Multi-scale assessment of roost selection by ʻōpeʻapeʻa, the Hawaiian hoary bat (*Lasiurus cinereus semotus*). . PLoS ONE 18(8): e0288280. https://doi.org/10.1371/journal.pone.0288280

Mortenson L.A., R.F. Hughes, J.B. Friday, L.M. Keith, J.M. Barbosa, N.J. Friday, Z. Liu, and T.G. Sowards. 2016. Assessing the spatial distribution, stand impacts and rate of *Ceratocystis fimbriata* induced ōhiʻa (*Metrosideros polymorpha*) mortality in a tropical wet forest, Hawaiʻi Island, USA. For Ecol Manag 377:83–92.

Peck, R.W., P.C. Banko, and M. Stelmach. 2014. Arthropod community structure on bark of koa (*Acacia koa*) and ʻōhiʻa (*Metrosideros polymorpha*) at Hakalau Forest National Wildlife Refuge. Hawaiʻi Cooperative Studies Unit Technical Report TR-HCSU-050. University of Hawaiʻi at Hilo, HI.

Pinzari, C.A., R.W. Peck, T. Zinn, D. Gross, K. Montoya-Aiona, K.W. Brinck, P.M. Gorresen, and F.J. Bonaccorso. 2019. Hawaiian hoary bat (*Lasiurus cinereus semotus*) activity, diet and prey availability at the Waihou Mitigation Area, Maui (No. HSCU-090). Hawaiʻi Cooperative Studies Unit, University of Hawaiʻi at Hilo.

Pinzari, C.A., M.R., Bellinger, D. Price, and F.J. Bonaccorso. 2023. Genetic diversity, structure, and effective population size of an endangered, endemic hoary bat, ʻōpeʻapeʻa, across the Hawaiian Islands. *PeerJ* 11:e14365 https://doi.org/10.7717/peerj.14365

Pratt, L.W. and J.D. Jacobi J.D. 2009. Loss, degradation, and persistence of habitats. Pages 137–158 in T.K. Pratt, C.T. Atkinson, P.C. Banko, J.D. Jacobi, and B.L. Woodworth (Eds.) Conservation Biology of Hawaiian Forest Birds: Implications for Island Avifauna. Yale University.

Poe, E.A. 2007. The effects of foraging habitat on the echolocation calls of *Lasiurus cinereus semotus* (Hawaiian hoary bat). M.Sc. thesis, Faculty of Graduate Studies, University of Western Ontario).

Racey, P.A. 1998. The importance of the riparian environment as a habitat for British bats. – In: Dunstone, N. and Gorman, M. L. (eds), Behaviour and ecology of riparian mammals. Symp. Zool. Soc. Lond. 71: 69–91.

Rainho, A., A.M. Augusto, and J.M. Palmeirim. 2010. Influence of Vegetation Clutter on the Capacity of Ground Foraging Bats to Capture Prey. Journal of Applied Ecology. Volume 47. Pages 850–858. doi: 10.1111/j.1365-2664.2010.01820.x

Rautenbach, I.L., M.B. Fenton, and M.J. Whiting. 1996. Bats in riverine forests and woodlands: a longitudinal transect in southern Africa. Canadian Journal of Zoology, 74:312–322.

Russo, D. and G. Jones. 2003. Use of foraging habitats by bats in a Mediterranean area determined by acoustic surveys: conservation implications. Ecography, *26*(2), pp.197–209.

Saint-Germain, M., C.M. Buddle, M. Larrivee, A. Mercado, T. Motchula, E. Reichert, T.E. Sackett, Z. Sylvain, and A. Webb. 2007. Should biomass be considered more frequently as a currency in terrestrial arthropod community analyses?. Journal of Applied Ecology, 44(2), pp.330–339.

Siemann, E., J.A. Carrillo, C.A. Gabler, R. Zipp, and W.E. Rogers. 2009. Experimental test of the impacts of feral hogs on forest dynamics and processes in the southeastern US. Forest Ecology and Management. 258:546–553.

Stone, C.P. and L.L. Loope. 1987. Reducing negative effects of introduced animals on native biotas in Hawaiʻi: what is being done, what needs doing, and the role of national parks. Environmental Conservation 14:245–258.

Taki, H., T. Inoue, H. Tanaka, H. Makihara, M. Sueoyoshi, M. Isono, and K. Okabe. 2010. Responses of community structure, diversity, and abundance of understory plants and insect assemblages to thinning in plantations. Forest Ecology and Management 259(3): 607–613.

Tetra Tech (Tetra Tech, Inc.). 2016. Final Nā Pua Makani Wind Energy Project Habitat Conservation Plan. Developed for Nā Pua Makani Power Partners. Available at: https://dlnr.hawaii.gov/wildlife/files/2018/12/Na-Pua-Makani-Final-HCP_March.pdf

Tetra Tech. 2023a. Kaheawa Wind Power Habitat Conservation Plan FY 2023 Annual Report. Available at: https://dlnr.hawaii.gov/wildlife/files/2024/01/Kaheawa-Wind-Project-I-FY2023-Annual-HCP-Report_f-1-1.pdf

Tetra Tech. 2023b. Kaheawa Wind Project II Habitat Conservation Plan FY 2023 Annual Report. Available at: https://dlnr.hawaii.gov/wildlife/files/2024/01/Kaheawa-Wind-Project-II-FY2023-Annual-HCP-report_f-1-1.pdf

Tetra Tech. 2024. Hawaiian hoary bat Tier 1 mitigation research plan. Prepared for Nā Pua Makani Power Partners, LLC.

Teixeira, D., M. Maron, and B.J. Rensburg. 2019. Bioacoustic monitoring of animal vocal behavior for conservation. *Conserv. Sci. Pract.* 1: e72. doi:10.1111/csp2.72.

Thompson, J. and L.A. Starcevich. 2022. Oahu Hawaiian Hoary Bat Occupancy and Distribution Study, Final Report. Dated July 2022. Prepared for: Hawai'i Endangered Species Research [sic] Committee. Available as Appendix 6 at: https://dlnr.hawaii.gov/wildlife/files/2022/12/Kawailoa-HCP-FY2022-Annual-Report_22DEC2022_final.pdf

Todd, C.M. 2012. Effects of prey abundance on seasonal movements of the Hawaiian hoary bat (*Lasiurus cinereus semotus*). M.Sc. thesis, University of Hawai'i at Hilo.

Todd, C.M., C.A. Pinzari, and F. Bonaccorso. 2016. Acoustic surveys of Hawaiian hoary bats in Kahikinui Forest Reserve and Nakula Natural Area Reserve on the Island of Maui. (No. HCSU-078, pp. 1–22). University of Hawai'i at Hilo.

Tomich, P.Q. 1986. Mammals in Hawaii. Honolulu: Bishop Museum Press. 375 pp.

Truxa, C. and K. Fiedler. 2012. Attraction to light - from how far do moths (Lepidoptera) return to weak artificial sources of light? European Journal Of Entomology 109, 77–84. doi: 10.14411/eje.2012.010

University of Hawai'i. 2023. Rapid ohia death. College of Tropical Agriculture and Human Resources. https://cms.ctahr.hawaii.edu/rod. Accessed September 18, 2023.

USFWS (U.S. Fish and Wildlife Service). 1998. Recovery plan for the Hawaiian hoary bat. Region 1. Portland, Oregon. https://ecos.fws.gov/ecp/species/770

Webber, B.L., B.A. Norton, and I.E. Woodrow. 2010. Disturbance affects spatial patterning and stand structure of a tropical rainforest tree. Austral Ecology 35:423–434.

Whitaker Jr., J.O. and P.Q. Tomich. 1983. Food habits of the hoary bat, *Lasiurus cinereus*, from Hawai'i. Journal of Mammalogy, 64(1), 151–152.

Williams, J.A., M.J. O'Farrell, and B.R. Riddle. 2006. Habitat use by bats in a riparian corridor of the Mojave Desert in southern Nevada. Journal of Mammalogy 87(6) 1145–1153.

Wilson, K.A. 1996. Alien ferns in Hawai'i. Pacific Science 50: 127–141.

Young, N. and J. Johnstone. 2011. Field methods for measuring plant species abundance: a comparison of visual cover estimates, presence/absence measurements, and the point-intercept method. Research summary prepared for the Integrated Arctic Terrestrial Vegetation Monitoring Workshop October 26-27, 2011. Available at: https://nwtdiscoveryportal.enr.gov.nt.ca/geoportaldocuments/field_methods_for_measurin.pdf

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# Figures

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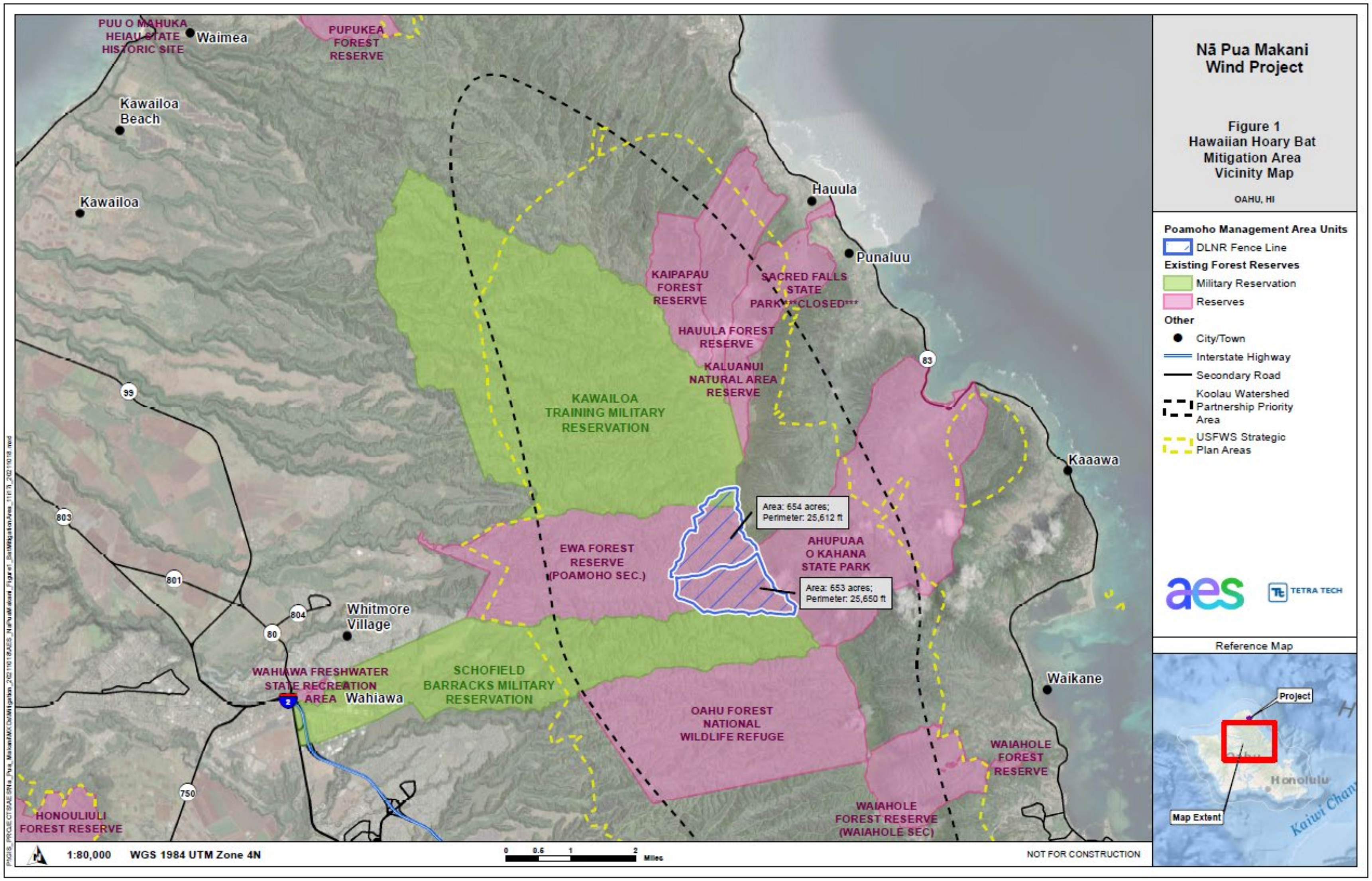

Nā Pua Makani Wind Project
Figure 1
Hawaiian Hoary Bat Mitigation Area Vicinity Map
OAHU, HI
Poamoho Management Area Units
DLNR Fence Line
Existing Forest Reserves
Military Reservation
Reserves
Other
City/Town
Interstate Highway
Secondary Road
Koolau Watershed Partnership Priority Area
USFWS Strategic Plan Areas
Reference Map
Project
Map Extent
Honolulu
Area: 654 acres; Perimeter: 25,612 ft
Area: 653 acres; Perimeter: 25,650 ft
PUU O MAHUKA HEIAU STATE HISTORIC SITE
Waimea
PUPUKEA FOREST RESERVE
Kawailoa Beach
Kawailoa
Hauula
Punaluu
KAIPAPAU FOREST RESERVE
SACRED FALLS STATE PARK***CLOSED***
HAUULA FOREST RESERVE
KALUANUI NATURAL AREA RESERVE
KAWAILOA TRAINING MILITARY RESERVATION
Kaaawa
EWA FOREST RESERVE (POAMOHO SEC.)
AHUPUAA O KAHANA STATE PARK
Whitmore Village
WAHIAWA FRESHWATER STATE RECREATION AREA
Wahiawa
SCHOFIELD BARRACKS MILITARY RESERVATION
OAHU FOREST NATIONAL WILDLIFE REFUGE
Waikane
WAIAHOLE FOREST RESERVE
WAIAHOLE FOREST RESERVE (WAIAHOLE SEC)
HONOULIULI FOREST RESERVE
1:80,000
WGS 1984 UTM Zone 4N
Miles
NOT FOR CONSTRUCTION

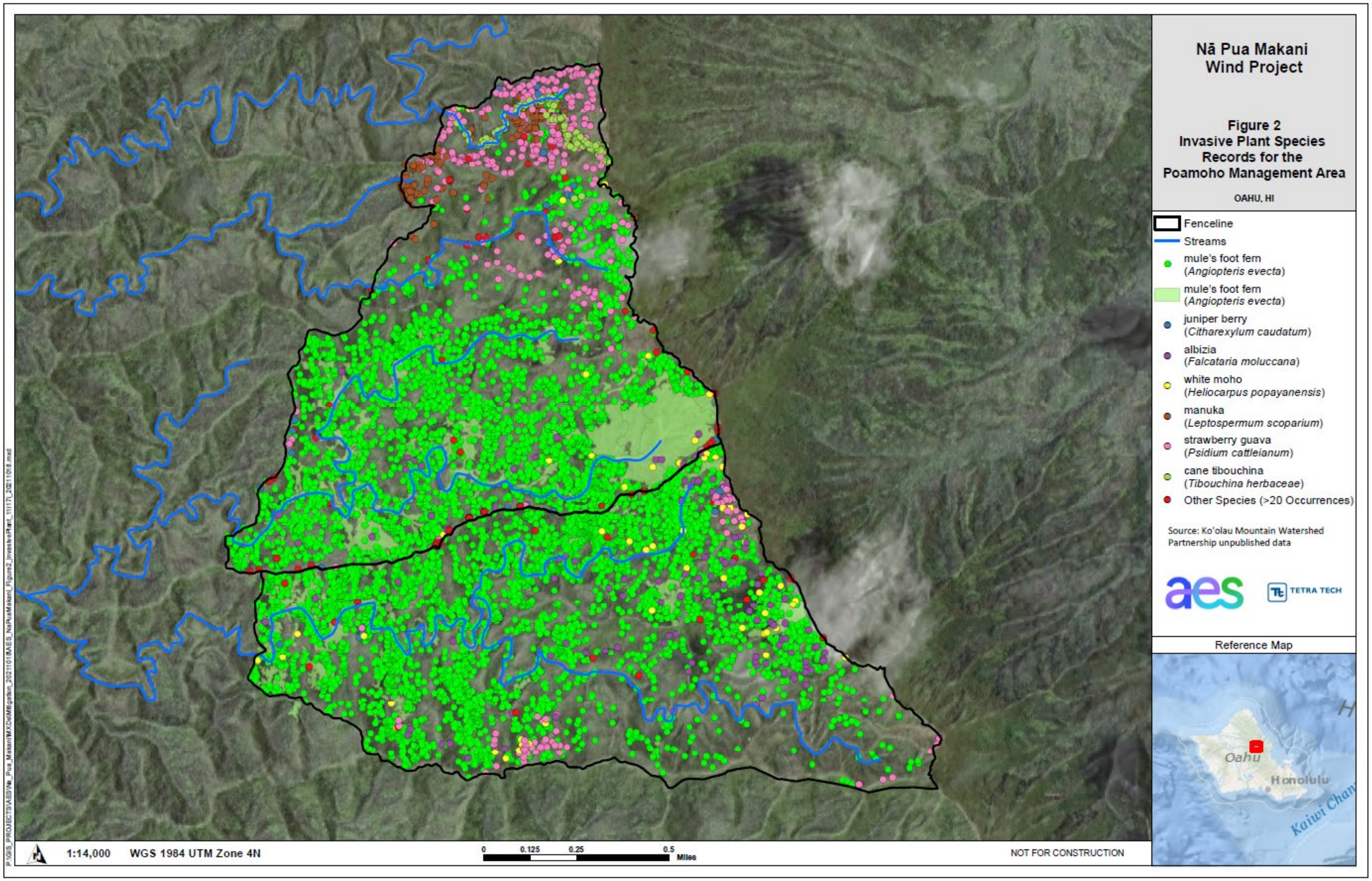
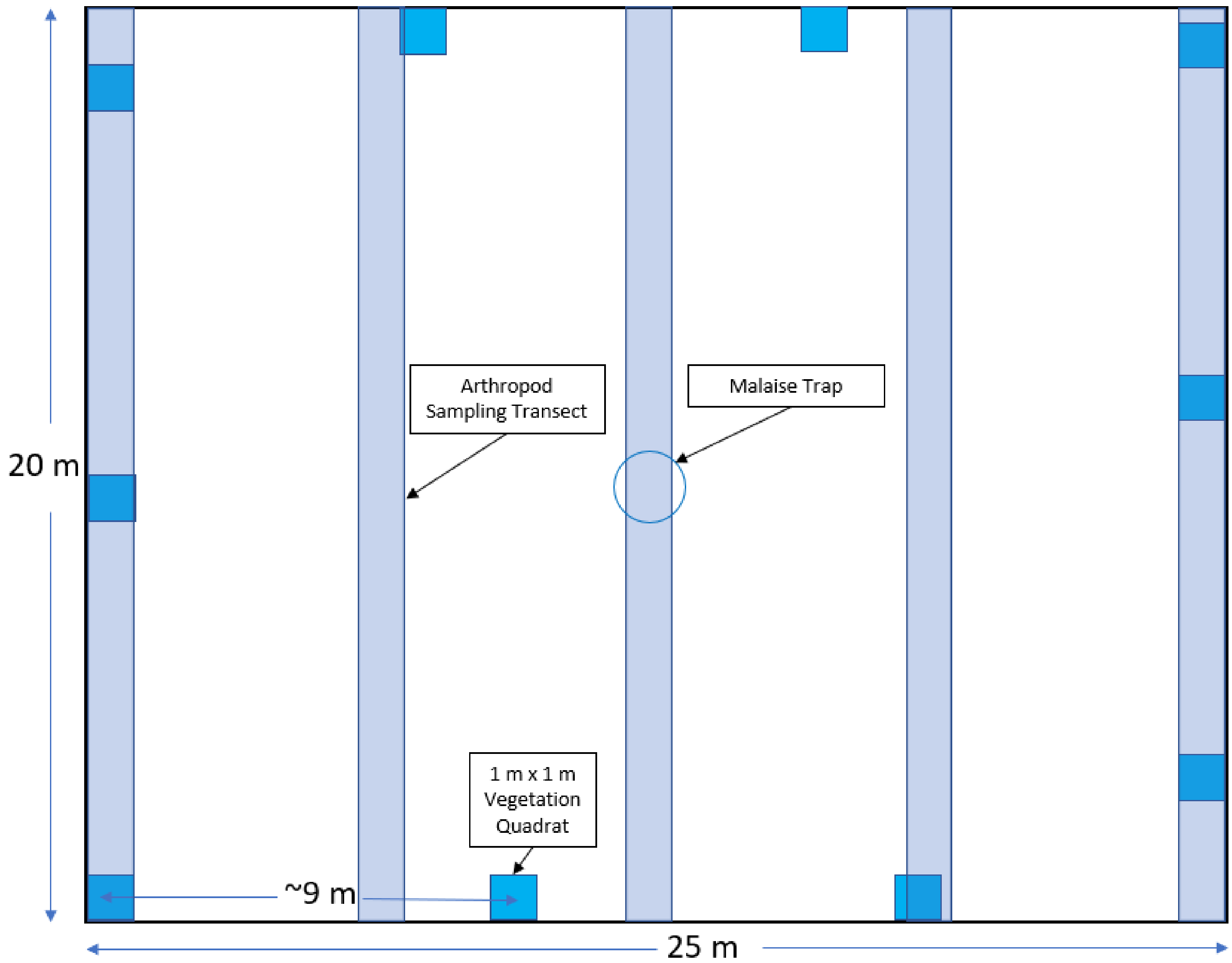
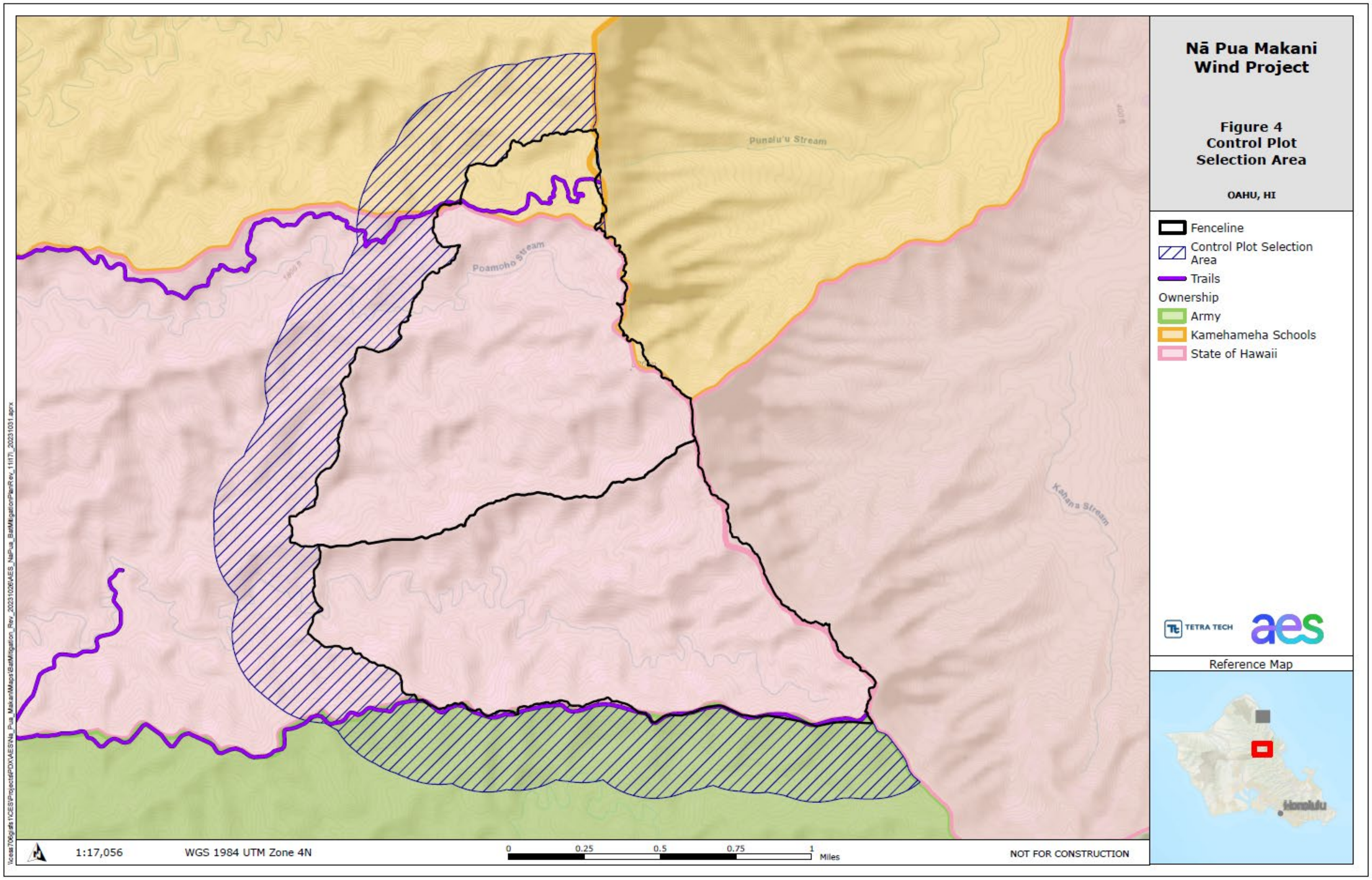

Nā Pua Makani
Wind Project
Figure 2
Invasive Plant Species
Records for the
Poamoho Management Area
OAHU, HI
Fenceline
Streams
mule's foot fern
(Angiopteris evecta)
mule's foot fern
(Angiopteris evecta)
juniper berry
(Citharexylum caudatum)
albizia
(Falcataria moluccana)
white moho
(Heliocarpus popayanensis)
manuka
(Leptospermum scoparium)
strawberry guava
(Psidium cattleianum)
cane tibouchina
(Tibouchina herbaceae)
Other Species (>20 Occurrences)
Source: Ko'olau Mountain Watershed
Partnership unpublished data
aes
TETRA TECH
Reference Map
Oahu
Honolulu
1:14,000
WGS 1984 UTM Zone 4N
0
0.125
0.25
0.5
Miles
NOT FOR CONSTRUCTION

**Figure 3. Example Planned Monitoring Plot Layout**




Nā Pua Makani Wind Project
Figure 4
Control Plot Selection Area
OAHU, HI
Fenceline
Control Plot Selection Area
Trails
Ownership
Army
Kamehameha Schools
State of Hawaii
TETRA TECH
aes
Reference Map
Honolulu
Punalu'u Stream
Poamoho Stream
Kahana Stream
1:17,056
WGS 1984 UTM Zone 4N
0
0.25
0.5
0.75
1
Miles
NOT FOR CONSTRUCTION