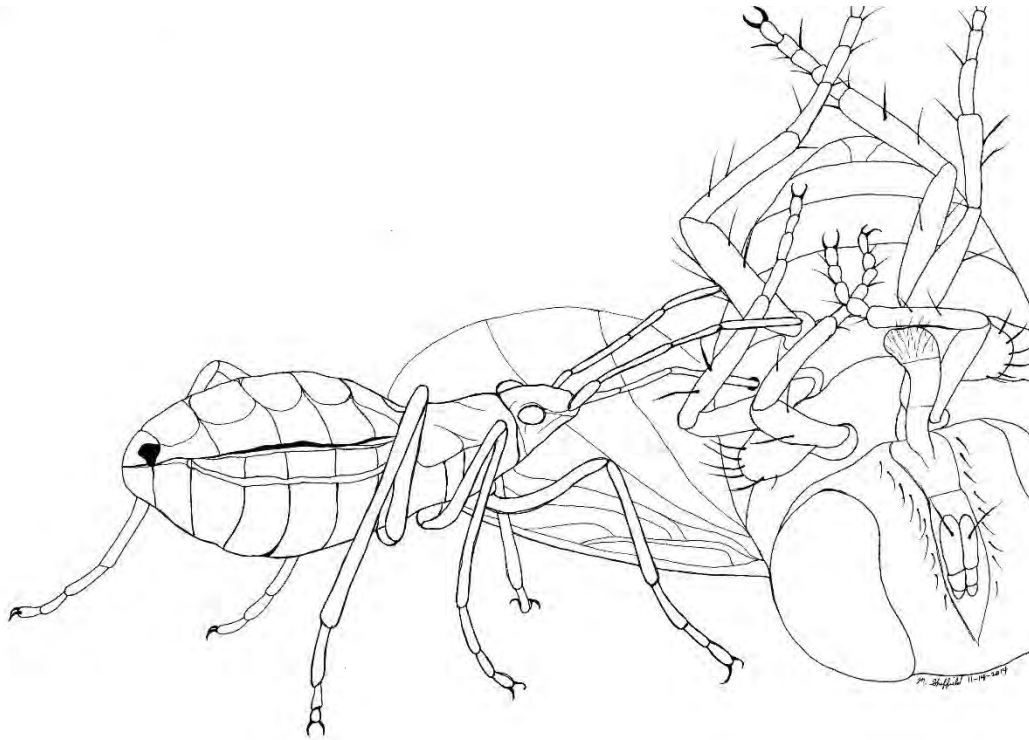


Maunakea Invasive Species Management Plan



The endemic Hawaiian Wēkiu Bug (*Nysius wekiuicola*) feeding on an introduced Flesh Fly (*Sarcophagid*).

Technical Report 191

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A cooperative effort of:



**Office of Maunakea Management
University of Hawai'i at Hilo**

-and-



**The Hawai'i-Pacific Islands Cooperative Ecosystems Studies Unit & Pacific Cooperative Studies Unit
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The Pacific Cooperative Studies Unit at the University of Hawai'i at Mānoa works to protect cultural and natural biodiversity in the Pacific while encouraging a sustainable economy. PCSU works cooperatively with private, state and federal land management organizations, allowing them to pool and coordinate their efforts to address problems across the landscape.

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Section 1. Introduction and Background

Foreword

The Maunakea Invasive Species Management Plan documents the objectives, policies and procedures of the Office of Mauna Kea Management for the prevention, detection and management of invasive plant and animal species on lands managed by the University of Hawai'i on Maunakea. The development and implementation of this plan supports the Office of Mauna Kea Management mission to achieve harmony, balance, and trust in the sustainable management and stewardship of UH managed lands (Mauna Kea Science Reserve and Halepōhaku) through community involvement and programs that protect, preserve, and enhance the natural, cultural, and recreational resources of Maunakea while providing a world class center dedicated to education, research and astronomy⁽¹⁾.

This document has been developed with the following guiding principles:

1. The high elevation areas of Maunakea are unique in the world, and the evolutionary processes, biodiversity and beauty of this area should be preserved in perpetuity,
2. There are no firm boundaries between the natural, cultural, recreational, or scientific resources of Maunakea and that all may be negatively impacted by invasive species,
3. Prevention and early detection is the most effective defense against the entry and spread of invasive species,
4. Planning and implementation of invasive species prevention and control programs are improved by input from, and participation by, the broader community and should incorporate the principles of adaptive management,
5. Management actions should be selected after careful cultural and scientific consideration of the risks and benefits of those actions against the survival and evolution in perpetuity, of the unique geology, flora, fauna and cultural values of Maunakea, at species, ecosystem and landscape scales,
6. All organisms are potential invasive species. The emphasis of this plan is on plants, invertebrates, and small mammals. Management of wildlife, such as game mammals and birds, are addressed in keeping with State of Hawai'i Department of Land and Natural Resources policies for Maunakea. These policies may conflict with those outlined in this plan.

Background

The Mauna Kea Science Reserve and Halepōhaku are 11,288-acre and 19-acre (respectively) areas of land leased by the University of Hawai'i from the State of Hawai'i for use as a scientific complex. In addition, the University has an easement for access between these two areas, referred to as the Summit Access Road Corridor. Management is guided by the 2009 Mauna Kea Comprehensive

Management Plan⁽²⁾ which provides the policy framework for the responsible stewardship and use of University-managed lands on Maunakea through to 2020. The Comprehensive Management Plan addresses the overall management of cultural, natural, research and recreational values of the precinct. It recognizes the threat posed by invasive species and mandates the development of an “*invasive species prevention and control program*” (p7-15, Management Action NR2).

The management policies for the natural values of the Mauna Kea Science Reserve are outlined in the Mauna Kea Natural Resources Management Plan⁽³⁾ which forms a sub plan of the Comprehensive Management Plan. This plan recognizes the threat and potential impact that non-native plants, animals and diseases can have on the unique and delicate ecosystems of Maunakea. It recommends the development of an invasive species management plan as a component of the “Threat Prevention and Control” strategy.

The five objectives listed in the Natural Resources Management Plan related to invasive species management are:

1. Prevent the introduction of new invasive species into the Mauna Kea Science Reserve,
2. Develop an early detection plan for invasive species within the management area,
3. Monitor established invasive species population and distribution,
4. Develop a rapid response program for incipient invasive species, and
5. Control established invasive species in sensitive areas.

This invasive species management plan also fulfills some of the requirements of the Hawai‘i Administrative Rules (HAR) and other statutes which either require or encourage consideration of invasive species concerns with other programs:

1. HAR 13-5-22 – Identified Land Uses in the Protective Subzone, P-4 Removal of Invasive Species. (While the University managed lands on Maunakea are in the resource subzone, all identified land uses and their associated permit or site plan approval requirements listed for the protective and limited subzones also apply to the resource subzone, unless otherwise noted.),
2. State Historic Preservation – invasive species management activities are designed to minimize impacts to historic resources, both by invasive species themselves and from control efforts, and
3. Institutional Animal Care and Use Committee (IACUC) requirements apply to any animal activities (IACUCs are a self-regulating entities that, according to U.S. federal law, must be established by institutions that use laboratory animals for research or instructional purposes to oversee and evaluate all aspects of the institution's animal care and use program.

Organization

This plan forms a component plan of the Natural Resources Management Plan⁽³⁾. It should be read within the context of this plan, and the parent Comprehensive Management Plan⁽²⁾. Unless deemed necessary for clarity, information already found within either parent plan shall not be duplicated here. This document is presented in two major parts:

1. The invasive species plan, containing the Office of Mauna Kea Management policies and general procedures as they apply to invasive species. As land zoned Conservation, Resource subzone – affecting an area greater than one acre – this portion of the plan requires site plan approval by the State of Hawai‘i, Department of Land & Natural Resources (Hawai‘i Administrative Rules, Chapter 13-5, August 2011), and
2. A series of appendices describing specific standards, activities and standard operating procedures required to fulfill the Office of Mauna Kea Management invasive species plan. These may alter from time to time as new methodologies are developed through the adaptive management process. The Office of Mauna Kea Management proposes that these changes be endorsed by the Mauna Kea Management Board and then submitted to the State of Hawai‘i, Office of Conservation & Coastal Lands (OCCL) for review and approval before formal adoption.

Education and outreach, addressing guiding principles such as obtaining input from, and participation by, the broader community (outside of cultural, recreation, and scientific users of Maunakea) is not directly addressed here. The Office of Mauna Kea Management anticipates preparing a programmatic document in the future which will include invasive species concerns as a community communication concern. A broad invasive species outreach strategy that engages the immediate cultural, recreation, and scientific users of Maunakea is appended.

As a policy document, it is likely to be read by people from a variety of backgrounds. In order to improve clarity for all readers, referencing and the use of scientific terms have been kept to a minimum.

Geography of the Management Area

For the purposes of this plan, the management area will be divided into five management zones, determined by the degree of risk each area poses to the entry of invasive species and the level of early detection or response activities required. These management zones are: 1) the Halepōhaku Visitor Information Station, 2) the road corridor to the summit, 3) the Astronomy Precinct, 4) Science Reserve, and 5) the Mauna Kea Ice Age Natural Area Reserve (NAR, managed by the Division of Forestry & Wildlife). These are outlined in the Figures below.

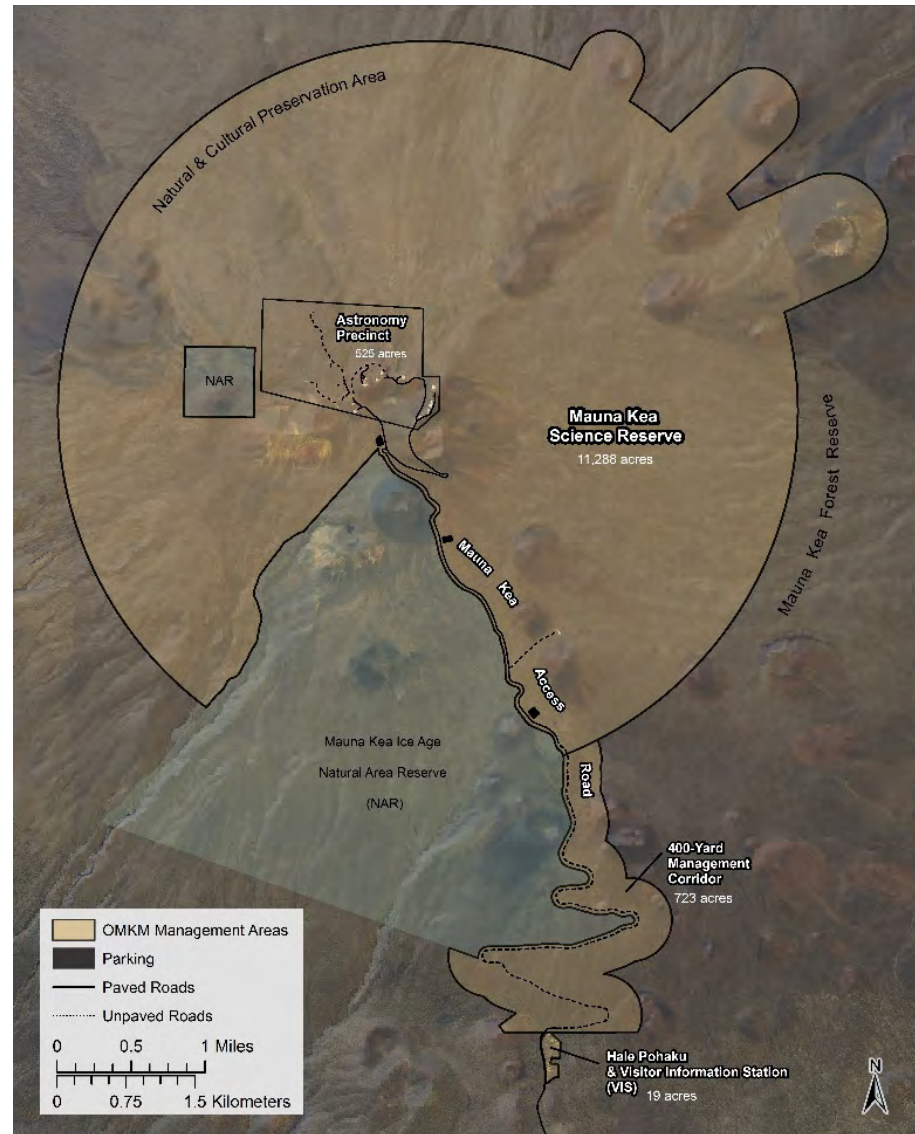
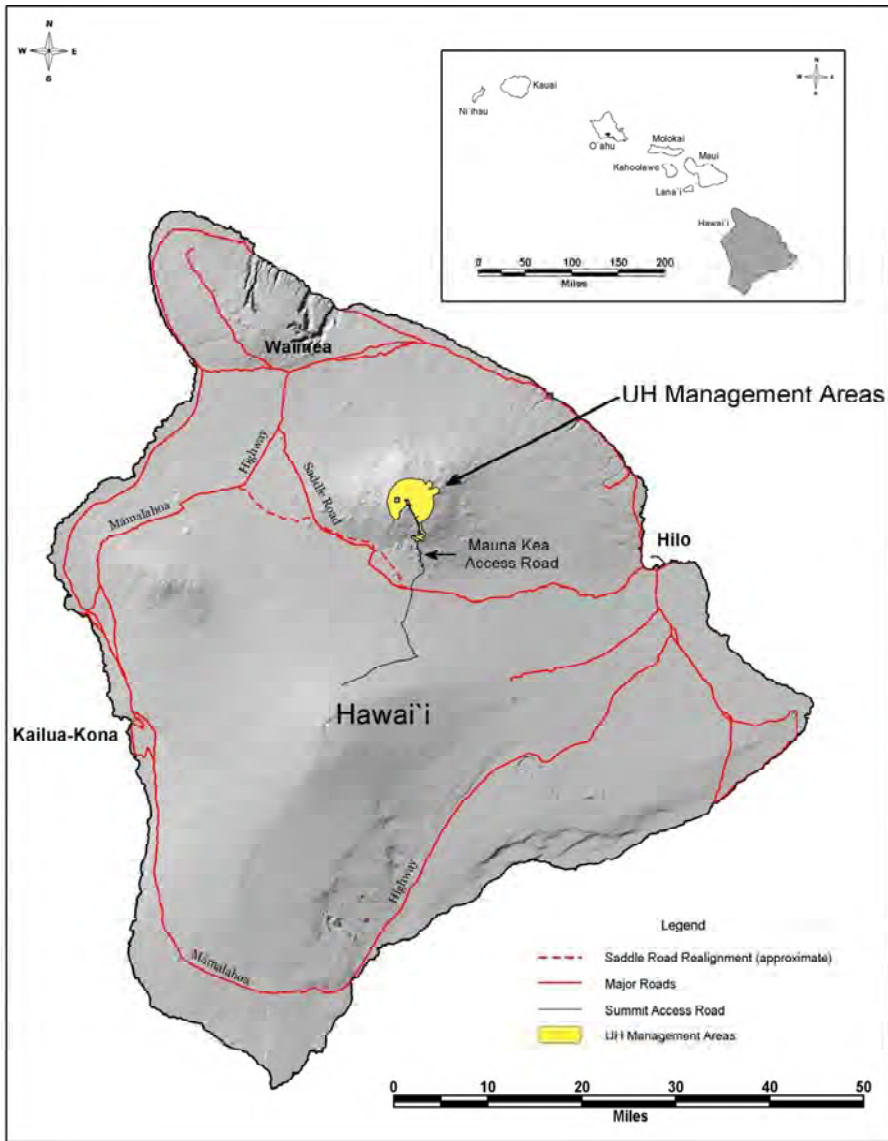


Figure 1.1. Map of the island of Hawai'i showing location of the Maunakea Management area.

Figure 1.2: Aerial view of the Mauna Kea Science Reserve.

HALEPŌHAKU

Situated at 9,200 ft. elevation, the mid-level facilities at Halepōhaku (TMK (3) 4-4-15:12) comprise 19.3 adjacent to the Summit Access Road. The entire parcel will be referred to as “Halepōhaku” in this document. The facilities include dormitories, a commons building, a construction camp, maintenance facility, and the Visitor Information Station (VIS). Both Halepōhaku and the VIS serve as a rest stop for staff and visitors, respectively, to acclimate before progressing to the summit. The VIS offers a gift shop, restrooms, and stargazing to over 500 visitors per day, 365 nights per year.

ROAD CORRIDOR

The Road Management Corridor as shown in Figure 1.2 extends from the top of the HP parcel to the bottom of the Science Reserve. While the actual Summit Access Road extends from the bottom of the HP parcel 8.3 miles to the Maunakea Summit, the lower 4.6 miles of which are unpaved. A 400-yard wide easement on either side of the road is described in the 1995 Management Plan, excluding portions inside the NAR. Acreage includes approximately 45-acres of road bed and 700-acres of easement.

ASTRONOMY PRECINCT

The 525-acre Astronomy Precinct, situated at the summit, was designated for the consolidation of astronomy facilities and support infrastructure in the University’s 2000 Master Plan. All but one existing observatory (the VLBA) are found within its borders, including the sites designated for the proposed Thirty-Meter Telescope⁽⁴⁾. The area is second only to Halepōhaku in human activity, which includes commercial tours, hiking, sightseeing, cultural expression, research, and snow play.

MAUNA KEA SCIENCE RESERVE

The largest portion of the UH Managed Lands is the Mauna Kea Science Reserve (MKSR) (TMK: (3) 4-4-15:09). The land is leased from the Department of Land and Natural Resource (DLNR) by the University of Hawai’i (UH). In its current form, the MKSR encompasses 11,288-acre of state land above approximately 11,500 ft elevation designated as a scientific complex. All MKSR lands outside of the 525-acre Astronomy Precinct are set aside as a Natural and Cultural Preservation Area.

The Summit Access Road is the only maintained road into the area, so that accessing much of the MKSR requires an arduous hike across the stone desert. Hiking time from the Astronomy Precinct to the outer edges of the Science Reserve is approximately four hours. Two unpaved hunting roads, shown as Skyline Drive and Maunakea Hunters Road (R-1) on state hunting maps provide access to the outer boundary of much of the MKSR, which is also a state hunting area. Travel time to remote areas via four wheel drive vehicle is not much improved over hiking from the Summit.

Cultural resources in the MKSR include at least 263 historic properties and several pu’u (cinder cones) which are designated Traditional Cultural Properties, including Kūkahau’ula, the cinder cone cluster that comprises the summit ⁽²⁾.

NATURAL AREA RESERVE (NAR)

The 3,894-acre Mauna Kea Ice Age Natural Area Reserve (NAR) is managed by the Hawai'i Division of Forestry and Wildlife, Natural Area Reserve Commission. The NAR was established in 1981 to protect an exemplary portion of invertebrate-dominated aeolian desert and the state's only alpine lake, Lake Wai'au. Prior to its establishment, the NAR had been part of the MKSR. The boundary follows the west side of the Summit Access Road, creating a large wedge, extending from approximately 10,000 ft to 13,441 ft, just below the summit. A second 143.5-acre square parcel is separately located around Pu'upōhaku, which also holds an ephemeral water source.

The Natural Area Reserves represent the highest level of habitat protection in the state land management system. Human activity in the NAR is restricted to hiking and observation of nature, permitted research, and staff management activities, which include monitoring and ungulate control. Under a 2008 cooperative agreement between OMKM and the Natural Area Reserves System (DLNR), OMKM provides visitor assistance using OMKM rangers, engages in joint research and educational efforts, and reports violations occurring in the NAR.

Lake Wai'au and its access trail (Maunakea-Humu'ula Trail) are of particular concern for invasive species establishment, due to both high levels of visitation and the constant water source. Introduced common dandelion (*Taraxicum officinale*) and two invasive carabid beetle (*Agonum c.f. muelleri* and *Trechus obtusus*) are established near the lake. Management of weeds along Summit Access Road requires coordination with the NAR, as OMKM jurisdiction ends at the road edge adjacent to the NAR and much of the power line easement for Maunakea extends through the NAR. The actions specified in this plan that occur in the NAR, require OMKM to obtain NAR permits and are otherwise conducted only with the explicit approval of NAR management.

Policies for Management of Invasive Species on Maunakea

The areas covered by this management plan include the Mauna Kea Science Reserve, Halepōhaku, the Astronomy precinct, the NAR and the Summit Access Road Corridor and shall be referred to in this document collectively as the “Management Area”. Management of invasive species within this area (whether established or potential threats), will be accomplished using a risk management approach. Risk management approaches recognize that the probability of an unwanted event occurring is difficult to quantify and rarely possible to prevent absolutely. A risk management approach attempts to balance the relative severity of a particular risk with the degree of effort needed to reduce the probability of its occurrence to a desired or predetermined level. One precept of this approach is that reduction of a particular risk to zero is not usually possible or practical. Further, the process should be transparent and inclusive, based on the best available data, open to change as new information becomes available and guided by the principle of continuous improvement.

There are five logical steps in the risk management process:

1. Identify potential threats,
2. Assess the impacts of these threats,
3. Determine the relative probability of occurrence,
4. Identify management options that reduce these threats, and
5. Prioritize management options based on return for effort and predetermined risk thresholds.

Section 2. Prevention

The keystone of this invasive species management plan is a strategy that prevents entry of new invasive species to the Management Area. Investment in prevention activities offers the greatest return for effort and should therefore take a high priority.

Potential Invasive Species: Threats and Impacts

PLANTS

Plants include grasses, herbs, vines, trees, fungi and legumes. Invasive plants can be spread via natural dispersal such as seeds caught in ungulate coats, carried on the wind, or through water erosion. However, the risk of accidental introduction is greater when vectored by people traveling to and from the Management Area on foot or in vehicles, buses, or via earthmoving equipment. Invasive plants tend to thrive in new locations due to a lack of the insects, diseases, and predators that usually control the species in its native habitat⁽⁵⁾. Without these natural inhibitors, the plants are able to spread aggressively. Spread is facilitated by a high rate of seed production, rapid growth to maturity, tolerance of different soil types and climate. Invasive plant species can create environment-altering impacts such as fire regime shifts, shade manipulation, lowering of the groundwater table and overcrowding. When invasive species become established, the entire ecosystem can potentially change as native plant species decline. Without native plant species, the native fauna that rely on these plants for food, shelter and hosts of prey items may be unable to survive.

Traits of invasive plants

Invasive plant species tend to have no natural enemies that regulate them in their new environment when compared with native plant species that are balanced by native viruses, insects, and/or herbivores. Without these checks and balances, invasive species often thrive in new environments to the detriment of the native species already present⁽⁶⁾.

Invasive plants often have short life cycles, which allows them to mature and reproduce more quickly than their native counterparts. This trait allows them to outnumber native plants in seed production, thus ensuring a competitive advantage. Invasive plant species also produce foliage and stay actively growing for longer periods. This allows for higher photosynthetic rates for longer periods of time, which, in turn, contributes to earlier maturity and seed production.

Many invasive plant species have a greater production rate of seeds which allows newly invasive plants to establish quickly with numerous offspring dispersed across large areas. Spread is aided by effective seed dispersal methods. Some species reproduce by vegetative means, and disperse by underground stems and cuttings that provide more opportunities for the plant to spread and multiply. Invasive species tend to evade grazing, often due to a lack of palatability to herbivores, while native species continue to be consumed yielding more room for the spread of introduced plants. Some invasive plant species are allelopathic, releasing chemicals into the soil that suppress growth of other plants⁽⁷⁾. They can also produce more shade than competing native plants, which

allows them to absorb sunlight more efficiently compared with native species in the understory. Finally, invasive plants tend to have long seed dormancy and staggered germination that give these species greater flexibility in germination and seasonality. These traits all contribute to the rapid spread of many invasive plant species.

Without a natural checks and balances system for invasive plant species, these plants have more energy they can use for growth and reproduction that would have otherwise been used to fight off diseases or heal from herbivores. Therefore, deep root systems can be developed relatively rapidly and early, which allows for a larger amount of water uptake from the soil. Not only does this provide the plant with more resources for energy production, but it also allows the plant to outcompete other natives trying to survive. These invasive plants produce dense root masses that prevent other native root establishment while producing a high capacity for carbohydrate storage in the roots. These dense root mats make control efforts difficult as their removal can be physically difficult and leave the area with highly erodible loose soils.

Target Species

The entry or establishment of any new plant species within the Management Area is undesirable. For prevention purposes, it is often difficult to identify potential propagative material (seeds, cuttings, seedlings etc.) at points of entry. Therefore, the most effective approach is to apply the “precautionary principle” to the entry of plant propagative material and assume all seeds, cuttings, seedling etc. are to be excluded from the Management Area.

VERTEBRATES

Several vertebrate groups are potentially invasive within the Maunakea Management Area, and are described below.

Cats.

A feral cat is a domesticated cat that has returned to the wild, or the descendants of such an animal. It is distinguished from a stray cat, which is a pet cat that has been lost or abandoned, while feral cats are born in the wild. The offspring of a stray cat can be considered feral if born in the wild. For the purposes of this plan, there is no distinction between feral and stray cats as their impacts will be identical. Cats introduced into areas in which they are not indigenous often cause harm to local environments by preying on local species. This is particularly true on islands, where feral cats have sometimes had a substantial and deleterious effect on the local fauna, especially birds. With the paucity of game animals and native birds within the Management Area, any cats present there are likely to turn to smaller prey such as invertebrates. Currently, cats are sparse at ~9,200 ft and above. They are occasionally observed, most commonly in late spring with green-up.

Mongoose.

The small Asian mongoose (*Herpestes javanicus*) is a weasel-like animal with a total body length of approximately 2 feet. It was introduced to Hawai'i Island in the late 1800's by sugar farmers in an attempt to control rodents in cane plantations. Since that time, they have spread throughout

the island, becoming a predator of birds and decimating native bird populations ⁽⁸⁾. They are very rarely observed at high elevations and virtually absent above 10,000 ft.

Rabbits.

The common domestic rabbit (*Oryctolagus cuniculus*) is rarely seen on Hawai'i Island, although occasionally reported on land adjacent to the Management Area. While rabbits can be a devastating pest in some locations, they are unlikely to survive within the Maunakea Management Area.

Mice and Rats.

Commensal rodents such as mice and rats are ubiquitous worldwide, often living in association with humans. In the Maunakea Management Area, they are most commonly associated with food preparation and handling areas at Halepōhaku and the Astronomy Precinct.

Dogs.

No established groups of wild or feral dogs have been observed in the Management Area. Occasionally hunting dogs become isolated from their handlers. These are usually returned to their owners.

Reptiles, frogs and amphibians.

The climate within the Maunakea Management Area is not suited to the survival of these species. Other than the occasional coqui frog sighting (which rapidly desiccates and dies), no reports of their presence are known.

Birds.

There are several invasive bird species on Hawai'i Island. The most serious are the Indian or common myna (*Acridotheres tristis*). This species was introduced to Hawai'i Island in 1875 and it quickly spread to occupy most low-elevation habitats. Indian mynas are not found above 7,500 ft elevation and are therefore unlikely to establish within the Management Area. The Japanese white-eye (*Zosterops japonicus*) is found within the Management Area however, and studies in the Hakalau Forest National Refuge, have shown that the presence of this species in Hawaiian songbird ecosystems stunts the growth of native bird species⁽⁹⁾.

Feral Ungulates.

Ungulate (hooved) animals include pigs, donkeys, sheep and deer. The association of introduced feral ungulates with the spread of invasive species and destruction of native flora on oceanic islands is well documented in Hawai'i and elsewhere. Ungulates graze on grasses and woody plants. The soil disturbance caused by hooves leads to soil erosion and facilitates the establishment of invasive plants. This management plan does not address management of feral ungulates within the Management Area as management activities are conducted by another agency and firearms, rifles, bows, and arrows are prohibited in the Halepōhaku area as part of the Conservation District Use Permit (HA-1430) for the site. However, The Office of Maunakea Management actively supports the DLNR decision to complete the Maunakea Palila critical habitat fence in the near future (2015) and to remove all feral ungulates from the summit area promptly.

INVERTEBRATES

Two invertebrate groups are potentially invasive in the Maunakea Management Area. Mollusks and arthropods are described below.

Mollusks

Terrestrial mollusks, include land snails and slugs, as there is no surface water on UH Managed Lands aquatic mollusks are not considered in this plan. Surface waters of Lake Wai'au and Pu'upōhaku are the responsibility of the Mauna Kea Ice Age Natural Area Reserve and any observations of aquatic mollusks will be reported to the appropriate management agency. There are no records of non-native snails in the Management Area, although native partulid and succinea snails are present in the Halepōhaku area. Any observations of terrestrial mollusks such as the giant African snail (*Achatina fulica*) shall be reported and responded to in the same manner as observations of invasive arthropods.

Arthropods

Arthropods include insects, spiders and related animals. Terrestrial arthropods are usually small and often cryptic. Many species can easily travel from location to location when associated with human commerce and movement. Although any new arthropod would be an unwelcome addition to the ecosystems in Maunakea, invasive ants pose one of the most serious risks.

Most arthropods are solitary creatures, only coming into meaningful contact with each other during mating events. Therefore in order to establish in a new location, both a male and female must be present and they must find each other in order to mate. Ants, however, are social insects having one or more queens and many sterile female workers per colony⁽¹⁰⁾. The queen usually only mates once in her reproductive life, and from that time onwards has the ability to produce new offspring: workers, new queens and males. Therefore, a colony or even a colony fragment with a single queen, has everything needed to produce new colonies and maintain the original one if moved to a new location.

Ants tend to be small, and ant colonies are usually well-hidden. For biosecurity purposes they form an ideal focus group for prevention strategies⁽¹¹⁾. It is highly likely that a biosecurity program that is able to successfully exclude invasive ants will also exclude most other crawling arthropods. For this reason, we propose to develop the arthropod component of the Maunakea invasive species (prevention) program around the exclusion of invasive ants.

TRAITS OF INVASIVE ANTS

Of the 15,000 or so ant species known to science, only a small fraction are invasive⁽¹²⁾. These species share a group of behavioral adaptations that pre-dispose them to successful relocation and establishment⁽¹³⁾.

- Polygeny,
- Polydomy and unicoloniality,
- High inter-specific aggression,
- Relocation via human commerce,

- Formation of mutualistic relationships.

Polygyny

Ants are typically monogynous. A monogynous colony consists of a single queen attended by many worker ants. The queen is the only reproductive ant and the workers are her daughters - sterile females. At times through the year, new queens are produced along with males. These fly from the nest at pre-determined times, mate in flight, and the newly mated queens land to form new colonies. Workers do not tolerate more than one queen per colony. Should two or more queens be present, the worker ants will assassinate the weaker queens.

Many invasive ant species are polygynous. Colonies of these species can contain many queens, and workers do not appear to distinguish between them or attempt to assassinate surplus queens. This feature gives colonies two competitive advantages. First, the founding phase of a new colony carries a high risk of failure. A newly mated queen needs to lay an initial clutch of eggs, care for them until the larvae reach adulthood, before focusing exclusively on egg-laying. New queens often suffer from predation or fail to raise sufficient workers to form a colony. For many invasive ant species, newly mated queens simply re-enter the parental colony, or move a short distance with existing workers to found a new colony. The probability of successful colony founding is much greater. As a result, most invasive ant species no longer need to take part in nuptial flights, instead mating within the nest.

The second advantage of polygyny is that the task of egg laying is now shared between a number of queens. This bestows a degree of redundancy for colony survival. In single queen colonies, the death of the queen heralds the end of the colony. Without new workers, the colony will decline and die. However, in multiple queen colonies, the death of one or more queens has no lasting effect on egg production. Remaining queens simply increase their rate of egg laying to compensate. This feature makes control of these species especially problematic. Many control methods focus on killing the queen for success. When many queens are present, this task becomes much more difficult.

Polydomy and Uniclonality

Ant colonies, even from the same species, are highly competitive and expend great resources to defend their territory and resources. Large amounts of energy may be expended in this activity. The importance of this battle for survival and territory should not be under-estimated. Almost all invasive ants share the traits of polydomy and uniclonality which dramatically reduces the costs of survival.

Colonies of the same species of invasive ants, however, do not compete with each other. They work cooperatively, share food, workers, brood and queens. In this way they form a network of connected colonies that together exclude all other ant species. Territorial defense is only needed at the outer edges rather than around each individual colony. This network of interconnected colonies is often called a "super-colony". Resources no longer need to be defended, and the energy previously used for defense is re-allocated to colony expansion. This aspect of invasive ant behavior is key to its invasive ability.

Inter-Specific Aggression

Coupled with the within-species cooperation is an aggressive defense of the entire super-colony. Any ants from another species that happens to be within the supercolony is overcome by sheer weight of numbers, and it is rare to find any other ant species within areas where an invasive ant species has become established.

Dispersal Ability

Most ant species disperse after mating; newly mated winged queens fly to other locations and establish new colonies. In contrast, most invasive ant species do not disperse by flight. Invasive ants only need a small colony of a few workers and one reproductive queen to be able to establish at a new location. Often, a complete colony is able to fit comfortably into an area smaller than a match-box. Increasing rates and volumes of human commerce provide the vector needed for invasive ants to move from location to location with little effort. This feature allows them to spread over long distances with little effort, or shorter distances through the movement of items such as potted plants, produce or other risk items.

Mutualisms

Another vital key to the success of invasive ants is their ability to capture and redirect sources of energy to themselves. One very important method these species utilize is via the formation of mutualistic relationships with homoptera (scales, mealybugs and other plant pests). Invasive ants “farm” these animals, protect them from natural predators and consume the sugary exudates these creatures produce. The additional energy this provides the colony is the fuel needed for further expansion and ecological dominance and one reason for their ability to form populations far more numerous than the ants they displace. Without access to these additional resources, population densities would be much lower.

Target Ant Species

Argentine Ants

The scientific name for the Argentine ant is *Linepithema humile*. Until recently it was known as *Iridomyrmex humilis*. Worldwide it is known as the Argentine ant. As its name suggests, this species was originally from South America with its native range centered on the Paraná river catchment which spans Brazil, Paraguay and Argentina. Argentine ants have been widely distributed by human commerce during the early part of the 20th century and are now found worldwide, including Europe, USA, South America, Australia, Africa and Asia as well as many islands in the Pacific. It is a common species on all the islands of Hawai‘i and is usually found at mid-high elevations, including sub-alpine portions of Haleakalā National Park (~9,700 ft). Sites closest to the Maunakea Management Area include: along the Saddle Road (including the Pu‘uhuluhulu parking lot), Keanakolu-Mana Road, and in Pōhakuloa Training Area. At lower elevations, it is out-competed by big-headed ants (*Pheidole megacephala*). This species prefers a Mediterranean climate with warm dry summers and cool wet winters. However, in the absence of competition from other ant species, it can establish and thrive in warmer and cooler climates. Argentine ants are a serious ecological pest, disrupting native ecosystems and is also a structural pest – often invading homes and urban buildings.

Little Fire Ants

The scientific name for this species is *Wasmannia auropunctata*. Around the world it is also known as the “cocoa tree ant” and the “electric ant”. Little fire ants (LFA) are originally from South America, east of the Andes. It has been spreading throughout the tropics and sub-tropics for over 100 years⁽¹⁴⁾. USA (Florida), Caribbean islands, west Africa, Israel, Papua New Guinea, Solomon Islands, New Caledonia, French Polynesia, Hawai‘i (Big Island and Kaua‘i), Australia, Galapagos, and Guam.

On the island of Hawai‘i, it is common and widespread from Kalapana to Laupāhoehoe up to an elevation of 2,000 ft and more sparsely distributed along the west coast between Kailua-Kona and Na‘alehu. Small populations have been found on Maui, Kaua‘i and O‘ahu. They prefer sites that are shaded, warm and moist, and generally avoid full sunlight. The association between little fire ants and homopteran plant pests can cause damage to the host plants and reduce productivity of fruiting trees and reduced growth of ornamental plants. Additionally, Little Fire Ants have a painful sting, and infested sites often have many millions of these ants per acre. Ants foraging on vegetation often fall to the ground and on people or pets. It is common for people in infested areas to suffer repeated stings on the neck, shoulders and torso.

White-Footed Ants

The scientific name for the white footed ant is *Technomyrmex difficilis*. This ant was previously identified as *Technomyrmex albipes* until 2007. It is also known as the “black house” ant around the world. Native to Southeast Asia, white footed ants have spread throughout the world mainly through the transport of cargo and other commodities. USA (Florida, South Carolina, Georgia, Louisiana, Hawai‘i), Antigua, Nevis, Puerto Rico, St. Croix and St. Thomas. In Hawai‘i WFA is currently known from Maui, O‘ahu and Kaho‘olawe. This species is a part of group of *Technomyrmex* species that look almost identical to one another, so it is probable this species may be established on other Hawaiian Islands. White footed ants will nest in almost any location inside and outside of the house including under roofs, cardboard boxes, compost piles, potted plants, outdoor furniture, etc... but trees seem to be ideal. Colony sizes can range from 400,000 to 3 million individuals. Because of the enormous size of the colonies, large amounts of food are essential to sustain the populations. WFA will feed on a wide variety of food sources including sugary substances, trophic eggs laid by worker ants and dead insects. White footed ants do not bite or sting. They are considered a pest primarily due to their high population densities and are also known to tend homopteran plant pests such as scale insects, aphids and mealy bugs and feeding on the sweet sugary honeydew produced by these insects. It has been documented that this association has contributed to the spread of several serious plant diseases around the world.

Singapore Ants

The scientific name for the Singapore ant is *Monomorium destructor*. It is also commonly known as the “destructive trailing ant” and “mizo-hime-ari” (Japan) around the world. Singapore ants are native to India, Japan, Malaysia and Sri Lanka and have spread to Australasia-Pacific, North America, South America, Africa, Laysan, French Frigate Shoals, and Hawai‘i. They are easily spread through commerce and trade. In Hawai‘i it is currently known to be established on Hawai‘i, Kaua‘i and O‘ahu. Singapore Ants are more of a pest in urban environments and as a house pest. Although

they will forage on sugars and proteins the biggest problem is the destruction of electrical and phone lines. Foragers gnaw holes in fabric and rubber goods, remove rubber insulation from electric and phone lines, and damage polyethylene cable. They can destroy or damage electrical lines in houses and cars which can lead to electrical fires.

Big-Headed Ants

The scientific name for the big headed ant is *Pheidole megacephala*. It is also known as the “brown house-ant”, “coastal brown-ant”, “lion ant”, and “grosskopfameise” (German) in other parts of the world. The big headed ant is believed to be native to southern Africa. It is widely distributed throughout the temperate sub-tropical and tropical regions of the world. Big headed ants get their name from the “major caste” of worker ants (often called soldiers) which have extremely large heads compared to the rest of their bodies. The smaller “minor caste” (small foraging ants) will forage on almost anything from sweet sugary liquids, dead insects, and plant seeds. They bring the food back to the nest where it is shared throughout the colony.

In rural areas, BHA are known to displace much of the native fauna through aggression and competition. They can directly impact crops through seed harvesting and indirectly by harboring plant sucking insects. BHA have also been known to chew through irrigation lines. They are a major pest of pineapples where they tend pineapple mealy-bug. In urban/residential areas they often cause considerable damage to telephone and electrical installations in homes and buildings.

Pennant Ants

The scientific name for the pennant ant is *Tetramorium bicarinatum*. It is also known as the “bicolored pennant ant”, “Guinea ant”, or “penny Ant”. The name Guinea ant is also commonly used for a close relative *Tetramorium guineense*. The genus *Tetramorium* contains several species known for dispersal via human commerce. The pennant ant is native to the Indo-Pacific region of the world. This is a cosmopolitan species commonly found around the world and is one of the most widespread species of ants globally. In Hawai‘i it is most likely established on all of the major islands. Colonies of pennant ants are usually small to moderate in size and occur in urban environments, yards, gardens, green/shade houses. Nests can have multiple queens and workers can vary in color and size. Although they are not considered to be a major pest, they can be a nuisance around the home and garden because of their ability to sting if provoked.

Potential Threat Pathways

A biosecurity “pathway” is defined as a mechanism by which an exotic organism can travel to a new location, often as a hitchhiker. For arthropods and plants, these pathways have been categorized into logical groups and further divided according to the level of control or regulation currently in force. These groups are: vehicles, commodities, and people (with associated personal items they may carry). A total of 28 different pathways have been identified.

Almost all inward movement of goods and people is via the road link which terminates at the Astronomy Precinct. Arthropods and plant seeds are potentially able to hitch a ride on the means of

transportation, the containers housing goods and other commodities, the goods or commodities themselves, or associated with staff or visitors. Each pathway represents a different risk of being the vector for introductions of exotic species.

There are also non-anthropogenic pathways including organisms carried by wind, rain, fire or other natural events. These have not been considered in this section of the risk assessment.

VEHICLES AND VESSELS

Vehicles of all descriptions can harbor many invasive pest species. Soil and other organic matter can accumulate in cracks, crevices and on under-bodies. Vehicles that travel to Maunakea originate from residential and urban areas on the island of Hawai'i. These locations harbor well-established populations of weedy, invasive arthropods and plants. Arthropods could infest a vehicle parked over-night and nest in the voids and other internal spaces, or in soil and other organic matter that accumulate in cracks, crevices and on under-bodies. Plant seeds can also be deposited on truck beds, under carriages or within a vehicle. These then fall off or leave when the vehicle is parked at another location. Larger vehicles and those used for off-road purposes usually have more soil and other matter attached to the underbodies and therefore present a greater risk. Passenger vehicles such as those used by staff and visitors are generally cleaner, as they tend to stay on County and State roads.

GOODS AND OTHER COMMODITIES

The movement of items to Maunakea (goods, commodities, supplies, equipment and construction activities) provide opportunities for arthropods and invasive plants to become established. The risks and species associated with the movement of goods are more diverse because some goods originate in other parts of the USA as well as internationally. Arthropods can hide in the goods themselves, the packaging associated with the commodities or within the containers used to transport them. Plant seeds, some very small, can be incorporated with packaging or moved by the wind to settle on commodities (especially those stored outdoors). Larger, or heavier, commodities typically have greater areas for species to settle and it can be more difficult to detect contamination. The level of risk for this pathway is influenced by storage conditions prior to arrival, the cleanliness of items, and the intrinsic properties of items as harbors for arthropods or plant seeds.

PEOPLE

People can inadvertently carry arthropods and seeds in their clothing or immediate possessions. Items especially high-risk would include packs, tents, camping equipment, shoes, and other items that may have been in contact with soil or stored in areas where ants and other arthropods were able to move into them prior to transport.

Regulated Pathways

Many of the vehicles, people and goods entering the Maunakea area require some form of permit in order to gain access. Risk reduction strategies can be more easily developed and enforced within

the permit system so therefore their actual risk level and mitigation options differ from those categories where a permitting system is absent.

VEHICLES AND VESSELS

Nine categories of vehicles have been identified, classified according to the type of cargo they usually carry:

1. regular staff vehicles (daily),
2. other staff (specific project, contractors),
3. delivery vans (daily-weekly supplies),
4. delivery trucks (telescope components),
5. delivery trucks (construction),
6. construction machinery,
7. helicopters ,
8. commercial tour vehicles,
9. film, scientific, educational, military.

COMMODITIES

Commodities come in all shapes and sizes, some are locally supplied while others arrive from overseas points of origin.

10. fresh produce,
11. packaged goods (food, office supplies, souvenirs),
12. containerized scientific equipment,
13. containerized construction supplies,
14. open-load construction supplies,
15. plants, seeds, plant parts, soil (outside - restoration),
16. plants, seeds, plant parts, soil (inside - staff decorations),
17. dunnage (the wrapping, packaging and pallet material associated with the goods being transported).

PEOPLE AND POSSESSIONS

People who are required to have a permit include regular employees, occasional employees, and those primarily engaged in outdoor activities.

18. Outdoor activities regulated by permits: scientific, film, project staff, military,
19. Regular employees,
20. Occasional employees and contractors.

Non-Regulated Pathways

Not all vehicles or visitors require a permit in order to visit the Maunakea area. Therefore the level of influence that can be applied to these pathways is less than that for regulated pathways. This may increase the risk and also influence the selection of most appropriate risk reduction strategy.

VEHICLES AND VESSELS

21. tourist sight-seeing vehicles,
22. off-road and ATV (outside of University managed areas),
23. hunters/hikers, snowplay, cultural practitioners.

COMMODITIES

24. cultural offerings,
25. trash (outdoors).

PEOPLE AND POSSESSIONS

26. Tourist/sightseeing
27. off-road operators (outside of University managed areas),
28. hunters/hikers, snowplay, cultural practitioners.

Analysis of Threat Pathways and Proposed Management Options

At present, most risk prevention measures are voluntary or suggested rather than being enforced. However, some risk prevention actions for future construction of a new telescope (TMT) are required conditions of their permit.

For the purpose of this document, proposed prevention actions focus on strategies for managing invasive species **prior** to their establishment within the Management Area or at its borders and below the Saddle Road – Summit Access Road junction (off-site risk reduction and interceptions). These are separate from those actions or activities conducted to detect and manage invasive species after their arrival (an “incursion”) which is outlined in Section 3; or management of invasive species already established within the Management Area (Section 4). Not every risk can be prevented or eliminated. Additionally, there are often external factors that increase risks but cannot be remedied. Therefore, any risk prevention strategy becomes a compromise limited by resources, external factors and practicality. Table 2.1a-d lists each pathway identified in the previous section along with prevention strategies requiring low, moderate and high inputs. Logically a greater amount of input will provide a greater level of risk reduction, and not every option (low, medium, or high) will be likely applied consistently across all pathways due to legal, practical, or other constraints.

Table 2.1a. Options for risk prevention (Regulated vehicles).

	Regulated pathways	Vehicles	Low cost	Moderate cost	High cost
1	regular staff vehicles (daily)		Outreach and/or mandatory awareness training		
2	other staff (specific project, contractors)				
3	delivery vans (daily-weekly supplies)		Outreach may include signage in car parks and staff break rooms. And displays of native and non-native invasive species encountered on regulated pathways.	Regular cleaning of vehicles (interior and exterior).	
4	delivery trucks (telescope components)			Mandated regular washing of vehicles using a gas station car wash or similar. This should include under-body washing.	Supervised or inspected power-washing of vehicles (especially under-bodies and chassis rails) along with interior cleaning.
5	delivery trucks (construction)			Frequency could be determined by risk – eg. passenger vehicles would be a lower risk than construction trucks.	
6	construction machinery				These provisions could be mandated by the appropriate permit via a requirement to wash and supplemented by OMKM inspections.
7	helicopters				
8	commercial tour vehicles		Training could consist of one-time or ongoing awareness and information sessions on impacts of invasive species and the need to maintain a clean vehicle to prevent transport of invasive species.	This requirement could be a part of relevant permit provisions.	Inspection/certification of vehicle cleanliness prior to arrival.
9	film, scientific, educational, military			Inspection/certification of vehicle cleanliness prior to arrival.	

Table 2.1b. Options for risk prevention (Regulated commodities).

	Regulated pathways	Goods	Low cost	Moderate cost	High cost
10	fresh produce		Outreach and/or physical inspection of items at destination.	Inspection/certification of goods and facilities prior to shipping (internal).	Inspection/certification of goods and facilities prior to shipping (external). Inspection of facility hygiene and shipments by an external agency or OMKM. Vendor facilities to undergo regular hygiene audits and goods to be inspected and certified free of pests before shipping. This could include phytosanitary inspections for plant material, visual inspections or other requirements as part of permit or approval conditions.
11	packaged goods (food, office, souvenirs)				
12	containerized scientific equipment		Outreach could include appropriate signage at receiving locations.	This mitigation may include requirements for facility hygiene (eg, a pest control program with licensed pest control company), storage of goods in appropriate conditions (off the ground, inside etc), and inspection of goods by vendor prior to shipment or at an intermediate transit site.	
13	containerized construction supplies				
14	open-load construction supplies				
15	plants, seeds, plant parts, soil (outside)		Goods arriving at buildings could be inspected by the person receiving them. Any suspect items or evidence of arthropods to be reported to appropriate authority.	May also include requirements for a statement of compliance from vendor with each shipment or supply contract and regular external compliance audit.	
16	plants, seeds, plant parts, soil (inside)				
17	dunnage	This could be voluntary or mandated.			

Table 2.1c. Options for risk prevention (Regulated persons).

	Regulated pathways	People	Low cost	Moderate cost	High cost
18	outdoor activities regulated by permits		Outreach and/or mandatory awareness training. Provision of outreach material highlighting risks	Voluntary guidelines for cleaning of equipment (tents, packs, shoes and clothing etc)	Mandatory cleaning of equipment (tents, packs, shoes and clothing etc) including spraying personal equipment with pesticides.
19	regular employees				
20	occasional employees and contractors				

Table 2.1d. Options for risk prevention (unregulated pathways)

	Non-regulated pathways	vehicles	Low cost	Moderate cost	High cost
21	tourist sight-seeing vehicles		Signage, pamphlets at visitor center, other outreach	Voluntary vehicle cleaning for regular visitors	Mandated washing of vehicles using a gas station car wash or similar. This should include under-body washing.
22	off-road and ATV				
23	hunters/hikers, snowplay, cultural practices.				
		goods	Low cost	Moderate cost	High cost
24	cultural offerings		Outreach and awareness activity especially for cultural offerings and practitioners.	Promote the concept that people take all trash home with them.	Strict “leave nothing behind” policy.
25	trash (outdoors)		Regular treatment of waste bins and surrounds with pesticides.	Voluntary guidelines for cultural practitioners. Regular treatment of waste bins and surrounds with pesticides.	Mandatory provisions for cultural offerings including hygiene, pretreatment with pesticides and limits on what can be brought.
		people	Low cost	Moderate cost	High cost
26	tourist/sightseeing		Signage, pamphlets at visitor center, other outreach	Voluntary guidelines for regular visitors and off-road/snowplay traffic.	Introduce permit requirements for high-risk categories.
27	off-road operators				
28	hunters/hikers, snowplay, cultural pract.				

Recommended Prevention Strategy

All prevention strategies will:

1. Mitigate biological, ecological, and human health risks on Maunakea and on the island of Hawai'i,
2. Prioritize preventative action prior to arrival at the Saddle Road Junction (i.e. at low elevation prior to arrival on University managed lands),
3. Be adapted and updated based on invasive species monitoring and inspection data, knowledge of pathways and species threats,
4. Apply the least intrusive means necessary (i.e. employ the lowest level efficacious prevention strategy option: low, moderate, or high cost), and
5. Incorporate concerns of mountain users and landowner.

Appended portions of this plan provide detailed instructions to all mountain users as to the required prevention strategies (summarized in Table 2.2). State and island of Hawai'i invasive species councils and committees will routinely be consulted, along with adjacent land-owners, to ensure practices are both 'state-of-the-art' as well as practical and necessary. These strategies are summarized below and in the following table.

Low-cost measures, which enhance mountain user knowledge of invasive species concerns on Maunakea, on the island of Hawai'i, and elsewhere, will be applied at the first opportunity. Examples of such low-cost measures applicable to all pathways and users include:

- Mountain user education and orientation,
- Bringing up only what is needed,
- Emphasis on cleanliness, and
- Self-inspection and self-verification (no verification or documentation required).

Moderate-cost measures incorporate low-cost measures. In addition moderate-cost measures will typically emphasize verification of recommended practices, with an emphasis on increasing understanding and user engagement including:

- Require practices of cleanliness and material minimization (rather than encourage them),
- Include verification of cleanliness by OMKM (or DLNR-approved inspectors), and
- Include documentation of inspections.

High-cost measures will typically include low- and moderate-cost practices as requirements, with independent documentation that actions have been completed and efficacious:

- High-cost measures will only be employed to prevent the greatest known or suspected risks.
- Third party sanitation action (cleaning, fumigation, etc.) required at point of origin.
- Independent documentation of sanitation conducted at point of origin.

- OMKM (DLNR-approved) inspection of sanitation completeness prior to proceeding above the Saddle Road Junction.

Prevention strategies for regulated pathways assume that OMKM has authority to require users to engage in recommended or required actions, both on and off University managed lands. These strategies are cumulative, such that a high-cost strategy incorporates all low- and moderate- cost elements unless stated otherwise. As identified elsewhere in this plan, prevention emphasizes pathways and areas frequented by people. Invasive species incursions by other ‘natural’ means such as wind or animal dispersion are addressed through early detection and rapid response procedures. While these strategies incorporate concerns of all users, ultimately all State of Hawai‘i laws, rules, policies, and permit requirements are incorporated.

Prevention strategies for non-regulated pathways will be updated once Hawai‘i Administrative Rules are approved and options for preventative actions are defined (i.e. actions can be required rather than only voluntary). Policies and procedures for non-regulated pathways are anticipated to employ similar prevention strategies to regulated pathways. An initial emphasis on outreach and education, voluntary at least until rules are in place, will allow opportunity to refine best communication practices.

Table 2.2. Recommended prevention strategies for entry of invasive species into the Management Area.

	Regulated pathways		recommended prevention strategy	Appendix Reference
1	regular staff vehicles (daily)	Vehicles	Moderate: outreach, training, regular cleaning, self-inspection with every trip	SOP 1
2	other staff (specific project, contractors)	Vehicles	Moderate: outreach, training, regular cleaning, self-inspection with every trip	SOP 1 & 2
3	delivery vans (daily-weekly supplies)	Vehicles	Moderate: outreach, training, regular cleaning, self-inspection with every trip	SOP 1 & 2
4	delivery trucks (telescope components)	Vehicles	Moderate: outreach, training, regular cleaning, self-inspection with every trip	SOP 1 & 2
5	delivery trucks (construction)	Vehicles	Moderate: outreach, training, cleaning, DLNR-approved biologist inspection	SOP 1 & 2
6	construction machinery	Vehicles	Moderate: outreach, training, cleaning, DLNR-approved biologist inspection	SOP 1 & 2
7	helicopters	Vehicles	Moderate: outreach, training, cleaning, DLNR-approved biologist inspection (not explicitly addressed due to limited occurrence)	SOP 1 & 2
8	commercial tour vehicles	Vehicles	Moderate: outreach, training, regular cleaning, self-inspection with every trip	SOP 1
9	film, scientific, educational, military	Vehicles	Moderate: outreach, training, regular cleaning, self-inspection with every trip	SOP 1 & 2
10	fresh produce	Goods	Moderate: outreach, training, cleaning, self-inspection, facility hygiene, documentation	SOP 1 & 3
11	packaged goods (food, office, souvenirs)	Goods	Low: outreach, training, self-inspection	SOP 1
12	containerized scientific equipment	Goods	Moderate: outreach, training, cleaning, DLNR-approved inspectors, pre-shipment inspection per permit.	SOP 1 & 2
13	containerized construction supplies	Goods	Moderate: outreach, training, cleaning, DLNR-approved inspectors, pre-shipment inspection per permit.	SOP 1 & 2
14	open-load construction supplies	Goods	Moderate: outreach, training, cleaning, DLNR-approved inspectors, pre-shipment inspection per permit.	SOP 1 & 2
15	plants, seeds, plant parts, soil (outside)	Goods	High: only approved with State-recognized and documented efficacy of existing phytosanitary treatment and DLNR-approved inspector	SOP 4
16	plants, seeds, plant parts, soil (inside)	Goods	High: only approved with State-recognized and documented efficacy of existing phytosanitary treatment and DLNR-approved inspector	SOP 4
17	Dunnage	Goods	Moderate: outreach, training, minimize use, cleaning, DLNR-approved inspectors, pre-shipment inspection per permit.	SOP 1 & 2
18	outdoor activities regulated by permits	People	Moderate: outreach, training, regular cleaning, self-inspection with every trip.	SOP 1
19	regular employees	People	Moderate: outreach, training, regular cleaning, self-inspection with every trip.	SOP 1
20	occasional employees and contractors	People	Moderate: outreach, training, regular cleaning, self-inspection with every trip.	SOP 1

	Non-regulated pathways			All: pending Administrative Rules
21	tourist sight-seeing vehicles	Vehicles	Moderate: outreach, orientation, voluntary cleaning.	
22	off-road and ATV	Vehicles	Not allowed on University managed lands. (Otherwise incorporate 'moderate' principles.)	
23	hunters/hikers, snowplay, cultural pract.	Vehicles	Moderate: outreach, orientation, voluntary cleaning.	
24	cultural offerings	Goods	Moderate: outreach, orientation, pack-it-out emphasis, voluntary guidelines for cultural practitioners.	+ Incorporate Constitutional protections
25	trash (outdoors)	Goods	Moderate: outreach, orientation, pack-it-out emphasis, pesticide treatment.	+ Pesticide use pending DLNR approval
26	tourist/sightseeing	People	Moderate: outreach, orientation, voluntary guidelines.	
27	off-road operators	People	Not allowed on University managed lands. (Otherwise incorporate 'moderate' principles.)	
28	hunters/hikers, snowplay, cultural pract.	People	Moderate: outreach, orientation, voluntary guidelines.	

Section 3. Monitoring for New and Established Invasive Species

General Principles

The prevention strategy outlined in section 2 is the first step in the continuum of invasive species management. This prevention strategy will be supplemented by a comprehensive and ongoing early detection and monitoring program that ensures new threats are quickly identified and managed according to pre-determined protocols; and established invasive species are monitored to determine spread and impacts. These activities allows for a rapid response with the highest probability of a successful outcome should new species be detected or the status of existing species change. There is considerable overlap between activities designed to detect new species and monitoring established populations. For this reason, these two aspects of the management plan have been combined.

Early detection and monitoring activities are to be prioritized in a manner that addresses the greatest risks; both in terms of invasive species with the greatest potential impacts and the sites where these species might first become established. Invasive species threats are divided into three categories for the purpose of this section (plants, arthropods and vertebrates). Monitoring methodologies within these groups are essentially the same, but substantially different between groups. The management zones within the entire UH-managed area have been divided according to their perceived risk and operational expediency. (For example, the road access between Halepōhaku and the summit includes lands with different tenure but a common purpose.)

Analysis of Risk: Management Zones

The probability of new species entering and becoming established within the Management Area is directly related to the level of human activity experienced at a particular site and proximity to anthropogenic structures (buildings, roads, earthworks). Early detection activities should therefore focus on sites with the greatest amount of human use. Below is a brief description of the management zones in decreasing order of risk.

HALEPŌHAKU

The mid-level Visitor Information Station and Onizuka Center for International Astronomy are located on a 19.3-acre site at the entry to the Management Area at an altitude of 9,200 ft A.S.L. These buildings mark the road entry to the Management Area. The Visitor Information Center is a staging point for public visitors and is comprised of a gift store, restrooms, picnic tables, and information center. The Astronomy Center houses scientists and technical staff. It is also used as a staging point for equipment, supplies and construction materials bound for the Astronomy Precinct on the summit.

Together, these sites experience the heaviest visitor and employee usage of the entire Management Area. The Office of Mauna Kea Management estimates that in 2014 over 40,000 vehicles visited the

Management Area above Halepōhaku [Hunter pers comm]. Of these, approximately 76% of vehicles were operated by members of the public (a non-regulated pathway) and it is reasonable to assume that many of these stop at the Visitor Information Station to acclimatize before either venturing further or returning.

Survey frequency and intensity needs to be greatest at these facilities. They receive more human and vehicular traffic than any other zone within the Management Area and much of the larger construction items bound for the summit are delivered here before transport to the summit. Additionally, the structures provide a variety of micro-climates, thus increasing the risk of establishment of non-native species⁽¹⁵⁾ and imply that control efforts around facilities which reduce the potential risk of spreading or facilitating establishment of non-native species are beneficial.

ROADWAY CORRIDOR

The road corridor connecting Halepōhaku with the summit and Astronomy Precinct comprises approximately 45-acres of road bed and 700-acres of surrounding undisturbed landscape. There are several small car parking areas along the road corridor between Halepōhaku and the Maunakea Science Reserve. All traffic to the summit of Maunakea travels along this road.

Human disturbance, especially soil disturbance is often implicated in facilitating the establishment and spread of invasive species⁽¹⁶⁾. This, coupled with the heavy vehicular use on this road increases the risk of entry, establishment and spread of new invasive species⁽¹⁷⁾ as well as those species already present within the Management Area.

The soil disturbed by road construction and regular grading provides a ready-made site for seed germination and plant establishment. Mean annual rainfall for this area ranges from 28" - 16", decreasing with elevation (Rainfall Atlas of Hawaii, <http://rainfall.geography.hawaii.edu/>). However, road construction results in the concentration of water in run-off ditches and culverts. This additional moisture will increase germination and survival especially for non-native plants. Therefore, road verges and nearby vegetation are to be surveyed on a regular basis.

ASTRONOMY PRECINCT

The 525-acre astronomy precinct is home to thirteen observatories with associated outbuildings; each staffed by scientific and technical personnel [Figure 3.1]. The structures at the summit each provide altered microclimates, potentially suitable for supporting invasive species not ordinarily able to establish at high altitudes. Within this management zone, vehicular and human movement is closely associated with structures (observatories, outbuildings and roads).

The Astronomy Precinct is situated at the summit of Maunakea, with most structures at elevations between 13,300 and 13,700 ft above sea level. The extreme altitude is not generally a good environment for plant establishment. However, the buildings can provide protection from extremes of wind and temperature and create a variety of microhabitats suitable for establishment of

introduced plant and animal species. Mean annual rainfall for this area is approximately 8", which increases with decreasing elevation into the Mauna Kea Science Reserve (Rainfall Atlas of Hawaii, <http://rainfall.geography.hawaii.edu/>). Road verges, again, provide better conditions for seed germination. Land not immediately adjacent to these structures is not as likely to provide adequate germination conditions.

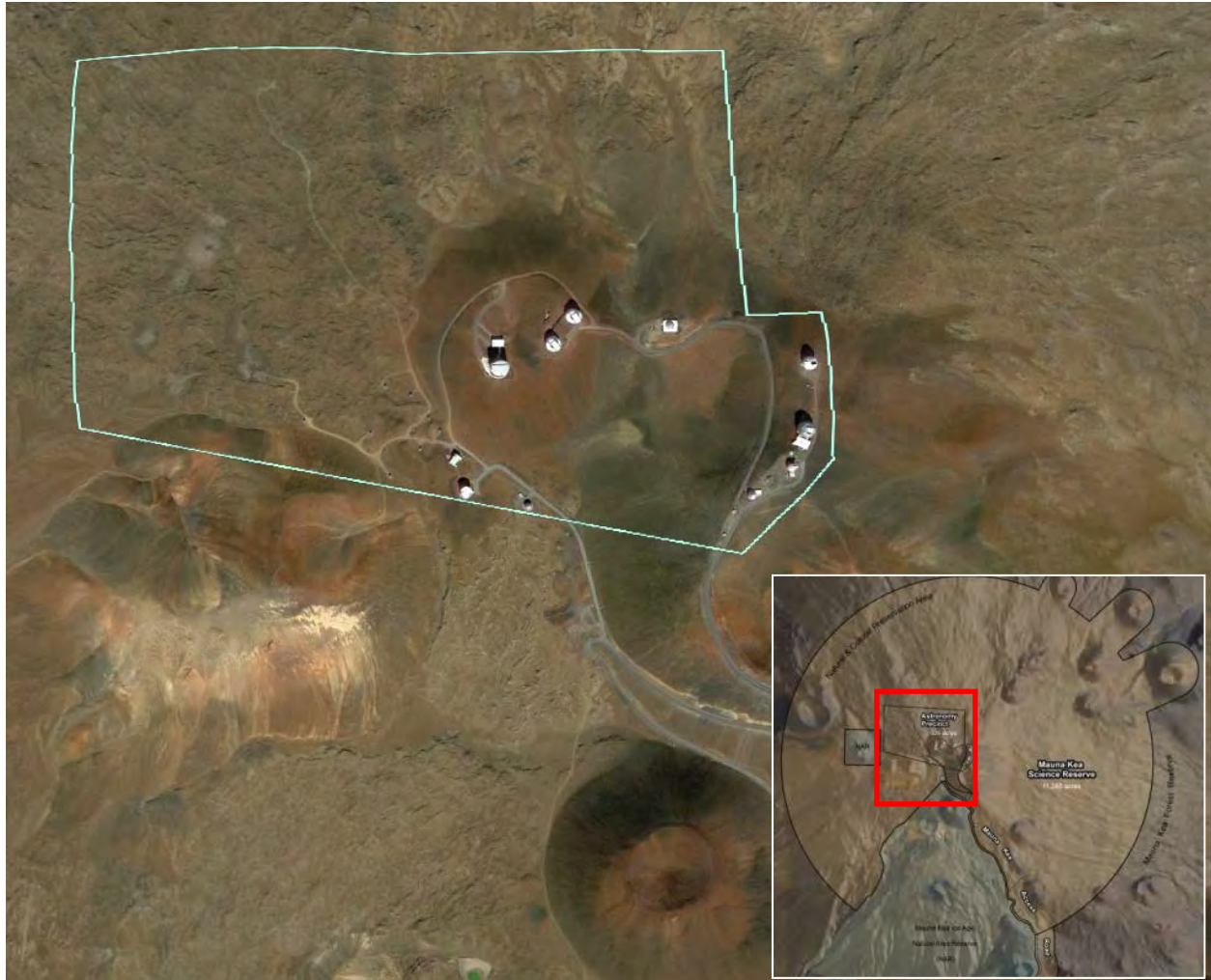


Figure 3.1 Aerial view of the Maunakea Astronomy Precinct with Maunakea Management Area (inset). Image taken from Google Earth accessed August 2014.

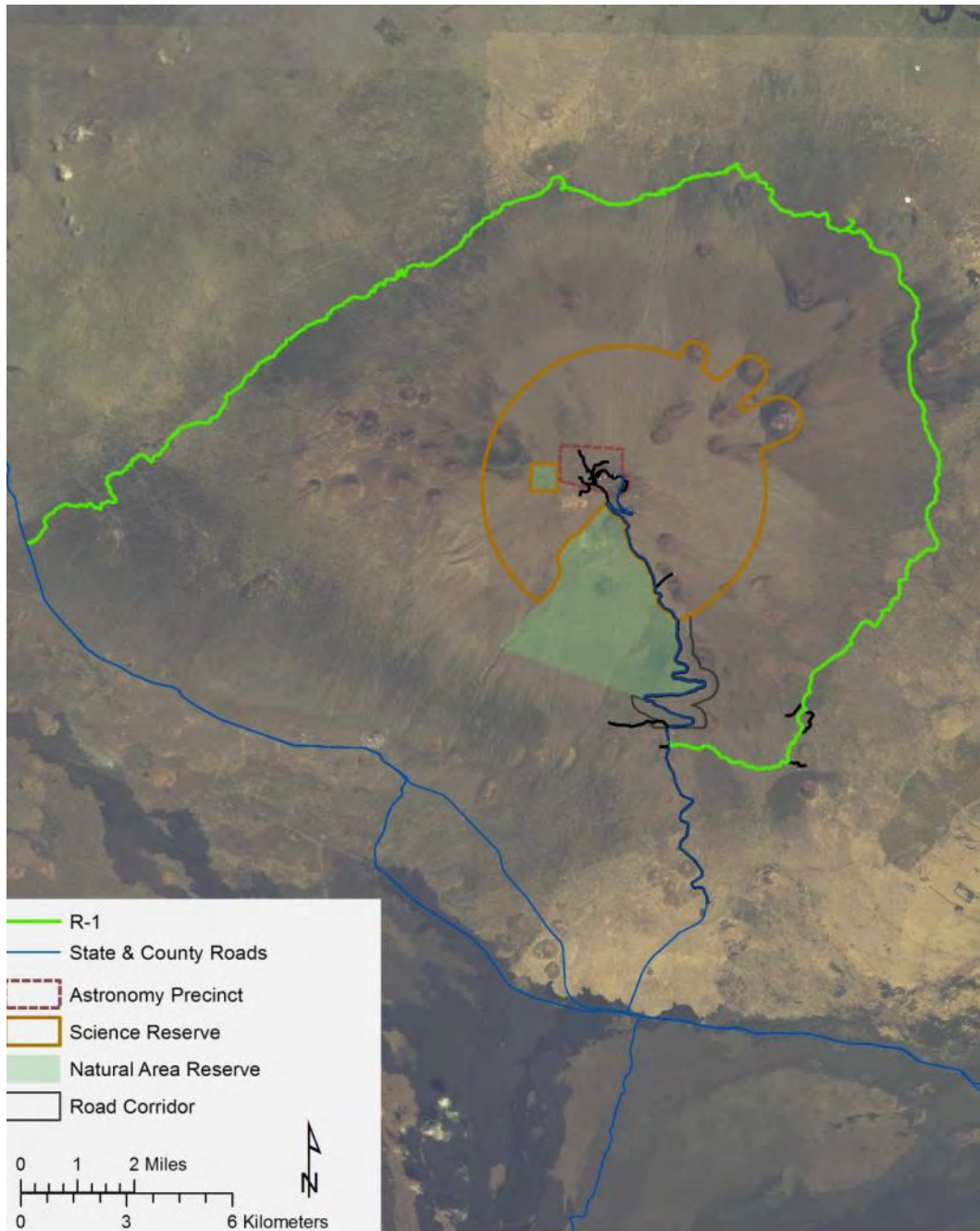
MAUNA KEA SCIENCE RESERVE

The remainder of the Management Area, known as the science reserve, covers an area of 11,288-acres. Human visitation to this area is lower than other management zones and is largely frequented by hunters, scientific staff and visitation to the various sites of cultural significance. Access to much of this area is difficult. The greatest risk of entry and establishment of invasive

species for this part of the Management Area is lateral movement of these species from neighboring lands. This presents an operational problem in relation to early detection and monitoring activities because the boundary between the Mauna Kea Science Reserve and neighboring lands is not associated with a road, trail or other navigable means of border patrol.

Systematic surveys of the entire 11,288-acre Science Reserve will be very resource-intensive and likely to be impractical. The nearest road to the lower boundary of this zone is the Maunakea Skyline Road known as the "R1"; a 32 mile road that (with a portion of the Saddle Road) circumnavigates Maunakea, running from immediately below the Visitor Information Station, and terminating at the Saddle Road (Figure 3.2). The R1 is a graded track suited to four wheel drive vehicles and motorcycles only, and is used frequently by the off-road community for scenic driving. This road provides an opportunity to intercept invasive plant and animal species that might travel through lateral spread to encroach on the Mauna Kea Science Reserve.

Figure 3.2. Aerial image showing the Maunakea Management Area and the roads immediately adjacent.



Analysis of Risk: Potential Threat Species

PLANTS

For the purpose of this section of the management plan, invasive plant species are; 1) already present on the Management Area; 2) not present but growing near the Management Area; or 3) not

present on Hawai'i island but identified as serious threats [Table 3.1, 3.2 and 3.3]. High priority species not present within the Management Area will be targeted in early detection surveys while those that are already present will be targeted for monitoring and response activities according to the level of threat they pose. These lists will change as new species are detected and new threats identified. A full list has been appended and will be updated as changes occur.

The potential "invasiveness" of plant species can be difficult to predict *a priori*. The Hawai'i Weed Risk Assessment⁽¹⁸⁾, based on earlier work in New Zealand⁽¹⁹⁾ is considered by many to be the current best-practice method for predicting invasiveness. The level of threat posed by a particular species is based on responses to 49 questions about a plant's biology, ecology & invasive tendencies elsewhere. The answers result in a score (the WRA score) that predicts whether a plant is likely to be invasive in Hawai'i. Plants with higher scores pose a greater threat than those with lower scores. The level of accuracy of this system is approximately 85%⁽¹⁸⁾, thus there is some uncertainty of results. The Hawai'i Weed Risk Assessment database will be used to rank all potential and current invasive plant species. Detection, monitoring and response actions will be based on the threat scores generated by this assessment method, supplemented by field observations of the species that indicate an increased or decreased level of threat compared with the HWRA score on file, and input from adjacent land-owners, knowledge of affects of altitude, and regulatory agencies.

The prevailing method for survey and monitoring of invasive plants is by visual searches, often conducted in association with physical removal of any exotic species that are encountered (when suitably qualified or trained staff are able to identify non-native species in the field). A complete list of mitigation methods is appended.

The Hawai'i Weed Risk Assessment score shall be determined for all non-native plants within the Management Area and those at risk from becoming established. Species with a score of 7 or less will be categorized as "low" priority; those that score between 8 and 16 shall be categorized as "medium" priority and those scoring 17 or higher shall be "high" priority species. Priorities shall be adjusted based on input from adjacent land-owners and regulatory agencies, and reflect control status of adjacent State land-owner practices unless eradication (or meaningful control) is practical exclusively on Management areas.

Low Priority Species

These plants are unlikely to degrade the Maunakea Management Area in an appreciable way. They may be small, spread very slowly or only by vegetative means. They should be pulled or destroyed if encountered in a destruction activity for other higher priority species.

Medium Priority Species

These species have characteristics that are undesirable, and may threaten or degrade the ecological, cultural or aesthetic values of the area. The distribution of these species are to be mapped and populations monitored to determine whether the WRA score is an accurate reflection of that species' "weediness". A control plan is to be prepared for each species or incorporated into management area control plans, (although such a control plan may not necessarily include treatment or destruction), and the invasive status be reported in annual reports.

High Priority Species

High Priority species are very invasive, have the ability to spread quickly and over-run the ecosystems they invade. Often, these species have additional negative impacts to environments, cultural and aesthetic values. For each high priority species present on UH-managed lands at Maunakea, a response plan will be prepared in accordance with the policies and procedures outlined in Section 5 (Emergency Response Planning, see Figure 5.2). This response plan will detail the level of response: eradication, aggressive control, long term management; after considering all available data.

The typical decision making process for response to these species is detailed in Figure 3.3.

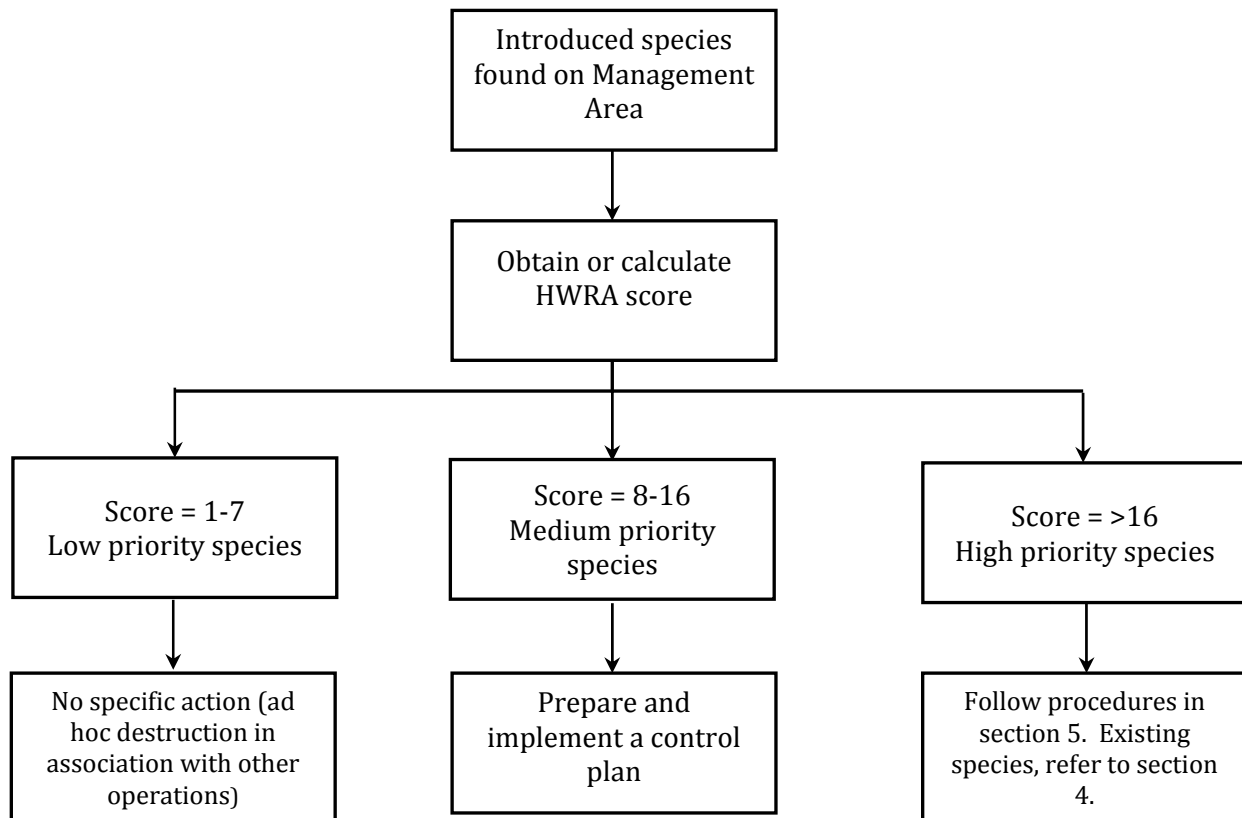


Figure 3.3. Process for managing introduced plant species on Maunakea Management Area.

Introduced Plant Species Currently Growing on the Maunakea Management Area

Monitoring and control procedures will be developed for all species currently growing on the Management Area. The complexity, level of involvement by oversight committees, and resources allocated to each species will be determined by the level of threat (biological, cultural and aesthetic)

they pose. Many species will see nominal control efforts, given their widespread presence on the island and threat level.

Table 3.1. List of introduced plant species present on the Management Area and HWRA score (where available).

<i>species</i>	common name	HWRA	Priority
<i>Achillea millefolium</i>	common yarrow	19	high
<i>Anthoxanthum odoratum</i>	sweet vernalgrass	11	medium
<i>Bidens pilosa</i>	spanish needle	23	high
<i>Bromus catharticus</i>	rescue grass		
<i>Bromus diandrus</i>	ripgut grass		
<i>Chamaecytisus prolifera</i> var. <i>palmensis</i>	broom (tagasaste)		
<i>Coreopsis lanceolata</i>	Ko'oko'olau haole, lanceleaf tickseed		
<i>Dactylis glomerata</i>	orchard grass		
<i>Ehrharta calycina</i>	perennial veldtgrass		
<i>Epilobium billardierianum</i>	willow herb		
<i>Erodium cicutarium</i>	alifaria, pin clover		
<i>Eschscholzia californica</i>	California poppy		
<i>Eucalyptus</i> spp.	eucalyptus		
<i>Gaillardia pulchella</i>	indian blanket		
<i>Geranium homeanum</i>	Australasian geranium		
<i>Heterotheca grandiflora</i>	telegraph plant		
<i>Holcus lanatus</i>	velvet grass		
<i>Hypochoeris radicata</i>	gosmore		
<i>Lepidium</i> spp.	peppergrass		
<i>Lolium</i> spp.	rye grass		
<i>Marrubium vulgare</i>	horehound		
<i>Mollugo cerviana</i>	carpetweed		
<i>Nassella cernua</i>	needlegrass		
<i>Oenothera stricta</i>	evening primrose		
<i>Pennisetum clandestinum</i>	kikuyu grass	18	high
<i>Poa annua</i>	annual bluegrass		
<i>Poa pratensis</i>	Kentucky bluegrass	14	medium
<i>Rumex acetosella</i>	sheep sorrel		
<i>Rytidosperma semiannulare</i>	wallaby grass		
<i>Senecio madagascariensis</i>	fireweed	23	high
<i>Senecio sylvaticus</i>	woodland ragwort		
<i>Senecio vulgaris</i>	common groundsel		
<i>Taraxacum officinale</i>	common dandelion		
<i>Tragopogon porrifolius</i>	salsify		

<i>Trifolium arvense</i>	<i>lance clover</i>		
<i>Verbascum thapsus</i>	<i>mullein</i>		
<i>Verbascum virgatum</i>	<i>wand mullein</i>		
<i>Verbena litoralis</i>	<i>ōwī</i>		
<i>Vulpia bromoides</i>	<i>brome fescue</i>		

Introduced plant species currently growing near or adjacent to the Maunakea Management Area Species not currently present on the Management Area, but known to be established on adjacent land (Table 3.2) are to be targeted in early detection/monitoring surveys (or on the island Table 3.3). These species could be transported to the Management Area by human-assisted dispersal (as seeds or propagative material carried on people, goods or vehicles) or spread from established populations growing near the external boundary.

The Halepōhaku, road corridor and the Astronomy Precinct are the most likely locations for establishment of new introduced plant species, so early detection surveys are to focus on those areas. The external boundary of the Management Area is not readily accessible for survey purposes. As a surrogate, the R1 road shall be surveyed for introduced plant species. These surveys are to record the identity and locations of any medium and high priority target species. Surveys of the remainder of the Science Reserve shall be limited to areas experiencing regular human traffic or concurrent with other management activities: known walking trails and cultural sites, historic property monitoring, etc.

Table 3.2. List of introduced plants growing on lands immediately adjacent to, but not within, the Maunakea Management Area (identified in reports published by Hakalau NWR, Mauna Kea Forest Reserve or NAR, or Department of Hawaiian Home Lands).

species	common name	HWRA	Priority
<i>Agrostis alba</i>	<i>redtop</i>		
<i>Andropogon virginicus</i>	<i>broomsedge</i>		
<i>Anemone hupehensis</i>	<i>Japanese anemone</i>		
<i>Axonopus fissifolius</i>	<i>narrow-leaved carpetgrass</i>	16	medium
<i>Cerastium fontanum</i>	<i>mouse-ear chickweed</i>		
<i>Conyza bonariensis</i>	<i>fleabane</i>		
<i>Cryptomeria japonica</i>	<i>sugi pine</i>	-3	low
<i>Delairea odorata</i>	<i>German ivy</i>	14	medium
<i>Ehrharta stipoides</i>	<i>weeping grass, meadow ricegrass</i>		
<i>Fuchsia spp.</i>	<i>fuchsia</i>		
<i>Hedychium gardnerianum</i>	<i>kahili ginger</i>	16	medium
<i>Ilex aquifolium</i>	<i>holly</i>		
<i>Juncus effuses</i>	<i>Japanese mat rush, common rush</i>		
<i>Lonicera japonica</i>	<i>Japanese honeysuckle</i>	12	medium
<i>Paspalum dilatatum</i>	<i>dallis grass</i>	12	medium

<i>Passiflora mollissima</i>	<i>banana poka</i>		
<i>Photinia davidiana</i>	<i>photinia</i>	-2	low
<i>Pinus spp.</i>	<i>pine</i>		
<i>Psidium cattleianum</i>	<i>strawberry guava</i>	18	high
<i>Rubus argutus</i>	<i>Florida blackberry</i>	21.5	high
<i>Rubus rosifolius</i>	<i>thimbleberry</i>	10	medium
<i>Stellaria media</i>	<i>common chickweed</i>		
<i>Tibouchina herbacea</i>	<i>glorybush</i>	24	high
<i>Ulex europaeus</i>	<i>common gorse</i>	20	high

An abbreviated list of introduced plants growing on Hawai'i Island is limited to: a) species previously eradicated from the Management area, b) species identified as invasive by adjacent land owners (i.e. the Maunakea Watershed Alliance), c) other species that potentially can survive and reproduce in the high elevation environment.

Table 3.3. List of introduced plants already found on Hawai'i Island, but not within the Maunakea Management Area or immediately adjacent lands (identified in reports published for Pōhakuloa Training Area).

species	common name	HWRA	Priority
<i>Angiopteris evecta</i>	<i>mule's foot fern</i>	8	medium
<i>Asclepias physocarpa</i>	<i>balloonplant</i>	8	medium
<i>Cirsium vulgare</i>	<i>bull thistle</i>	18.5	high
<i>Clidemia hirta</i>	<i>Koster's curse</i>		
<i>Coccinia grandis</i>	<i>ivy gourd</i>		
<i>Ficus rubiginosa</i>	<i>Port Jackson fig</i>	7	low
<i>Fraxinus uhdei</i>	<i>tropical white ash</i>	11	medium
<i>Grevillea robusta</i>	<i>silky oak</i>	5	low
<i>Kalanchoe tubiflora</i>	<i>maternity plant</i>		
<i>Lophospermum erubescens</i>	<i>creeping gloxinia</i>	5	low
<i>Melastoma candidum</i>	<i>Asian melastome, Malabar malastome</i>	13	medium
<i>Miconia calvescens</i>	<i>miconia</i>	14	medium
<i>Morella faya</i>	<i>firetree</i>	8	medium
<i>Nicotiana glauca</i>	<i>tree tobacco</i>	15	medium
<i>Passiflora tarminiana</i>	<i>banana poka</i>	24	high
<i>Pennisetum setaceum</i>	<i>fountain grass</i>	26	high
<i>Ricinus communis</i>	<i>castor bean</i>	21	high
<i>Rubus ellipticus</i>	<i>yellow Himalayan raspberry</i>	18.0	high
<i>Salsola kali</i>	<i>tumbleweed</i>	18.5	high
<i>Schinus terebinthifolius</i>	<i>Christmas berry</i>	19	high
<i>Setaria palmifolia</i>	<i>palm grass</i>		
<i>Solanum Pseudocapsicum</i>	<i>Jerusalem cherry</i>		

<i>Sphaeropteris cooperi</i>	<i>Australian tree fern</i>	8	medium
<i>Tibouchina urvilleana</i>	<i>princess-flower</i>	10	medium

Survey design and frequency: invasive plants

The frequency and scope of early detection and monitoring activities are determined by the level of risk that each management zone presents relative to other zones. The Halepōhaku and road corridor zones are the highest risk areas due to the high levels of human visitation and movement of commodities. The Astronomy Precinct receives lower visitation and the areas away from roads and buildings are less amenable to germination and growth of introduced species. The Science reserve has the lowest visitation, and human activity is limited to trails and cultural sites. Hunters, hikers, scientific, and Office of Mauna Kea Management staff are the most frequent visitors for the remainder of this zone. These personnel possess an enhanced awareness of the dangers of invasive species and more likely to take preventative actions prior to embarkation. Table 3.4 lists the frequency, type and scope of surveys for introduced plants. Survey methods to be used for these activities are appended.

Table 3.4. Survey frequency and scope for detection and monitoring introduced plant species.

Management Zone	Survey type	scope ¹	Survey frequency
Halepōhaku and Road corridor	Established and potential threat species	All land within 300ft of structures and within 60ft of roads and parking lots	Twice annually
Astronomy precinct	Established and potential threat species	All land within 150ft of structures and within 60ft of roads and parking lots	annually
Science Reserve	Established and potential threat species	Trails and cultural sites, sites with established introduced species	Minimum every 2 years, remote sites less frequent
R1 road	Potential threat species only ²	All land within 30ft of road verges	Minimum every 2 years

VERTEBRATES

Aside from dogs and feral ungulates, cats, mongoose and rodents are the greatest vertebrate threat to the Management Area. Mongoose are rarely encountered and are to be reported as-seen. Commensal rodents (mice and rats) are most prevalent in conjunction with human habitation. Feral cats are occasionally encountered. Introduced birds, while common, have no known control methods for an otherwise unbounded Management Area; and as mentioned previously environmental conditions are not known to provide suitable habitat for reptiles and amphibians.

¹ Once a high or moderate priority species is detected, survey to delimit the extent will continue beyond the distances listed below.

² Established introduced species may also be recorded as determined by Office of Mauna Kea Management.

There is no existing consistent risk analysis for introduced vertebrates as there is for plants. Rather priorities are set in consultation with Federal and State wildlife management agencies.

Survey design and frequency: invasive vertebrates

As outlined in the introduction, The Office of Mauna Kea Management has no legal authority for managing feral ungulates and other game species. However, current practice at Maunakea is to search for scat (dung), on an *ad hoc* basis, collate and map the resulting data. The latest map, prepared by OMKM (Figure 3.4) shows the majority of ungulate activity within the road access corridor, Visitor Information Center and the Astronomy precinct. This may reflect survey effort in these areas as opposed to the density of target species.

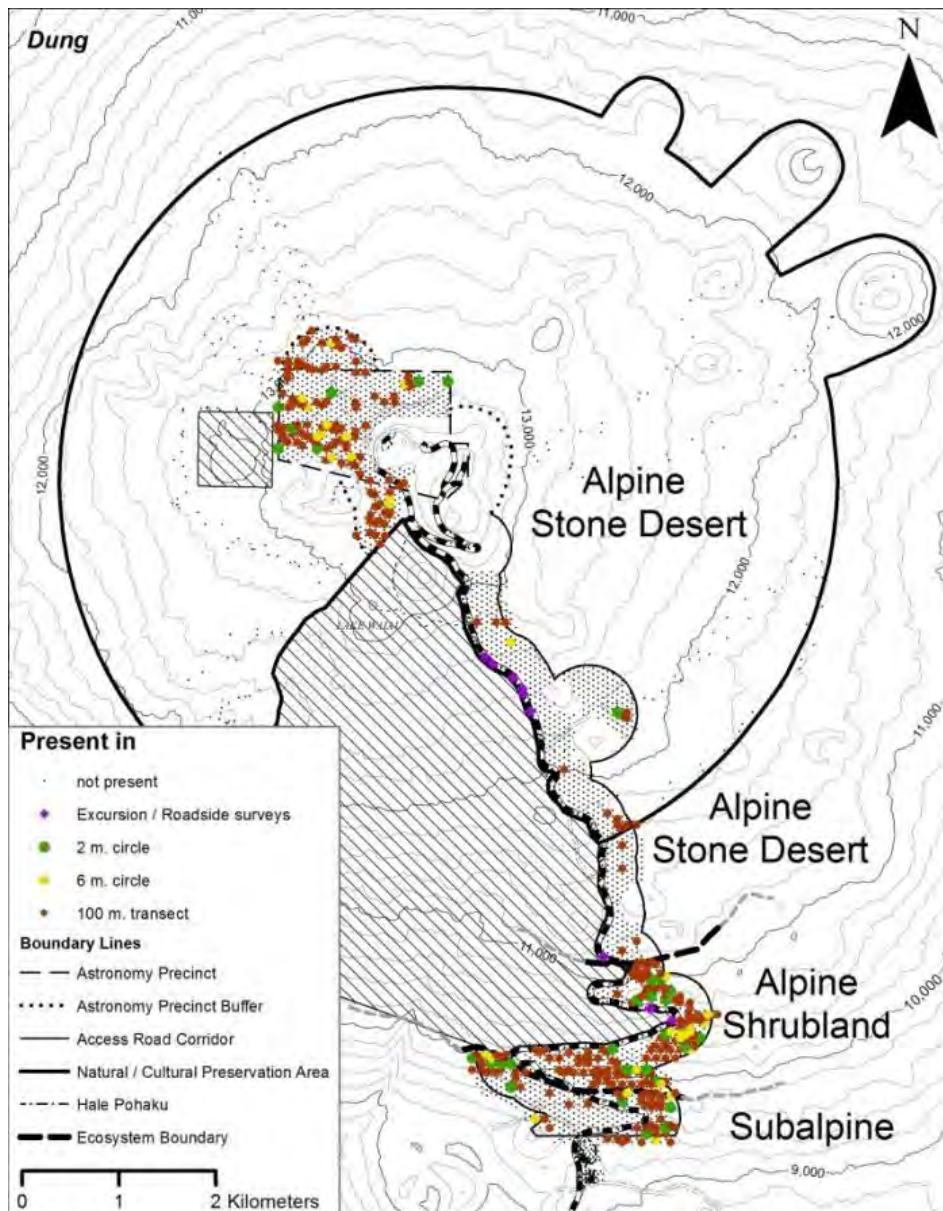


Figure 3.4. Location of animal scat and survey method, Maunakea Management Area, 2004.

The Office of Mauna Kea Management does not actively control vertebrate pests such as ungulates and game animals. However, staff may observe these animals during normal duties and these sightings should be reported in a manner that spatial data may be compiled to assist other agencies with managing these species. Encounters with animal scat should also be documented.

Surveys and monitoring for commensal rodents (rats and mice) and feral cats will be conducted to Institutional Animal Care and Use and Committee (IACUC) standards. All buildings and other structures will be kept free of mice and rats using a control system that conforms to current standards. Additional sightings of mice, rats or harborage beyond these areas will be reported by Office of Mauna Kea Management as they come to hand (see Table 3.5 for summary).

Table 3.5. Survey frequency and scope for detection and monitoring vertebrates.

Management Zone	Survey type	scope	Survey frequency
Halepōhaku	Report sightings of dogs, ungulates and mongoose as encountered. Ongoing rodent pest control program in and around structures	ad hoc annual report per IACUC standards	ongoing
Road corridor	Report sightings of ungulates and mongoose as encountered. Report scat and evidence of vertebrate use (grazing, harborage etc.)	ad hoc coordinated with NAR program	ongoing
Astronomy precinct	Report sightings of ungulates and mongoose as encountered Ongoing rodent pest control program in and around structures	ad hoc annual report per IACUC standards	ongoing
Science Reserve	Report sightings of ungulates and mongoose as encountered. Report scat and evidence of vertebrate use (grazing, harborage etc.)	ad hoc	ongoing
R1 road	No survey		

ARTHROPODS

Invertebrates (arthropods) have great potential to alter the ecological functioning of the Management Area as well as impacting on the integrity of cultural resources and human health⁽²⁰⁾. The greatest potential impacts are most likely to be caused by “social insects” (ants, wasps, bees and termites). These insects live cooperatively and have the greatest potential to establish and

spread. For example, the Argentine ant (*Linepithema humile*) has successfully invaded Haleakalā National Park on Maui and spread to elevations above 9000 ft⁽²¹⁾, reducing abundance of other invertebrates including pollinators of the Haleakalā silversword (*Argyroxiphium sandwicense subsp. macrocephalum*). Once established, social insects are very difficult to control or eradicate, often requiring substantial human resources and materials.

The following groups of invertebrates are the high priority target species for both early detection and ongoing monitoring (appended invertebrate identification guide will be updated more frequently than this document):

1. **Ants** (Order: Hymenoptera, Suborder: Apocrita, Family: Formicidae) and other taxa that are morphologically similar, i.e. look like ants,
2. **Wasps** (Order: Hymenoptera, Suborder: Apocrita, Families: Vespidae, Pompilidae, & Mutillidae) and other taxa that are morphologically similar, i.e. look like large wasps. [Excluded are: Suborder Apocrita, Families: Bradynobaenidae, Falsiformicidae, Rhopalosomatidae, Sapygidae, Scoliididae, Sierolomorphidae, Tiphidae]],
3. **Spiders** (Order: Araneae),
4. **Beetles** (Order: Coleoptera) [Excluded are Suborder: Polyphaga, Family: Coccinellidae – i.e. ladybugs),
5. **Horn & Stable Flies** (Order: Diptera, Suborder: Brachycera, Family: Muscidae, Subfamily: Muscinae, Tribe: Stomoxyini)
6. **Centipedes** (Order: Scolopendromorpha, Family: Scolopendridae, Genus: Scolopendra), and
7. **Mollusks** (Phylum: Mollusca).

Survey design and frequency: invasive arthropods

There are numerous methods to survey and monitor for non-native arthropods, including mollusks. In natural or outdoor areas, visual searching, pitfall trapping and deployment of vials baited with food lures are the predominant methods. Sweep nets are an effective method to survey insects in shrubs and low vegetation. Larger trees can be surveyed by physically jolting the stem and catching arthropods in trays as they fall. The most effective (and time-consuming) survey method for taller vegetation involves fogging the canopy with a non-residual pesticide and collecting all insects that fall with a sheet laid on the ground.

Of the methods listed above, visual searches and pitfall trapping are most likely to capture a variety of species groups. Visual searching (with trained staff) is the most efficient. However, when monitoring for a single species, there may be superior species-specific methods available.

Indoor sampling methods include visual surveys and baited glue boards. Glue boards shall be deployed on an ongoing basis in areas near arthropod habitat (warm areas, close proximity to water, shelter or food). Boards can be inspected at pre-determined intervals. Recommended survey frequencies are listed in Table 3.6.

Table 3.6. survey frequency and scope for detection of and monitoring for introduced arthropod species.

Management Zone	Survey type	scope	Survey frequency
Halepōhaku	Baited and un-baited pitfall traps supplemented by visual searches as pitfall traps are retrieved. Weed pull around facilities.	distributed across entire parcel	twice annually
	Baited glueboards indoors	indoors in facilities	monthly
	Baited glue boards, vials outdoors	outside of facilities	quarterly
Road corridor	Visual searches and array of baited and unbaited traps	entire road corridor, emphasis on pull-outs, parking areas, trailheads, etc.	annually
Astronomy precinct	Visual searches and array of baited & unbaited traps	roadway, facilities, and undeveloped areas	annually
	Baited glueboards and visual searches	all facilities indoor and outdoor	quarterly
Science Reserve	Quadrat surveys along paths and walking trails. Thorough visual survey and baited vials around cultural sites	trail survey to comprise 5% of trail length	minimum every 2 years, remote sites less frequent
R1 road	Visual searches within quadrats on high side of roadway	total quadrats to comprise 1% of road length	minimum every 2 years

Section 4. Control of Established Invasive Species

General Principles

Non-native plant and animal species established within the Management area have the potential to impact the cultural, environmental and aesthetic values of the Maunakea landscape. However, management actions designed to mitigate these impacts also have the potential to affect the very values they aim to protect. Control actions therefore, must be selected after careful consideration of all factors including cultural and social issues. Often, the course of action eventually selected will be a compromise between ecological, aesthetic and cultural costs and benefits.

The selection of response methods is to be made after full consideration of the following questions:

1. Will the proposed response have a reasonable probability of achieving the desired objective or outcome?

Often there are several possible response or control methods available to decision makers. It can be difficult to determine the exact probability of a successful outcome when comparing methods, however, it may be possible to determine (by Bayesian or group consensus) which methods are likely to be effective. Those that are unlikely to be effective should not be selected without changing the objective and acknowledging the reasons for changing objectives.

2. Does the proposed response adhere to best practice pest control principles of using the least toxic method to achieve the desired objective or outcome?

The ideal of best-practice pest control is to employ the least toxic method using the least amount of pesticide necessary to achieve the desired level of control. Following this best-practice guideline ensures the lowest possible level of non-target or environmental impact. This ideal includes selection of methods that are more target-specific than other options.

3. Are anticipated non-target impacts an acceptable cultural, environmental or aesthetic cost?

There may be instances where certain control options could potentially result in unwanted impacts on the environmental values or to other organisms living in association with the non-native species being controlled. The costs (unwanted impacts) must be weighed against the benefits (removal of the target species) in a way that allows an informed decision to be made. At times, non-target impacts may be an acceptable cost in order to prevent even larger impacts from the non-native species, and in other situations the unwanted impacts are not acceptable.

4. What are the consequences of taking no action or selecting a response method with lower efficacy?

There may be conflicts between a desire to use non-pesticide methods (physical, cultural or biological controls) rather than conventional use of pesticides to achieve a pest control objective. These conflicts may be influenced by social or cultural desires to employ methods deemed more

“natural”. While this document does not attempt to determine which course of action is most appropriate, it is important to fully consider the costs (economic, environmental and cultural) when making these decisions.

Legislation and Regulatory Requirements

The use of pesticides is subject to federal, state and sometimes county laws, statutes and regulations. Laws and regulations relating to the use of pesticides, herbicides, rodenticides and fungicides on the Management Area are administered by the following agencies:

THE ENVIRONMENTAL PROTECTION AGENCY (EPA)

All substances used for the control of plant and animal pests must be registered with the Environmental Protection Agency in accordance with the Federal Insecticide Fungicide and Rodenticide Act (7 U.S.C. §136 et seq.) (1996). Also known as FIFRA, this act (and associated legislation) regulates pesticide use, distribution and sale.

HAWAI‘I DEPARTMENT OF AGRICULTURE

The HDOA Pesticide Branch administers Hawai‘i Revised Statutes chapter 149 (Hawai‘i Pesticides Law) and associated Hawai‘i Administrative Rules Chapter 66. Almost all pesticides used in the state of Hawai‘i must have both EPA and Hawai‘i registration.

The use of pesticides in a manner that does not comply with the product label (off-label use) requires a permit from HDOA Pesticides Branch. There are several permit types that may apply for control activities within the Management Area:

Special Local Need Permit

A Special Local Need (SLN) permit may be issued by HDOA in order to allow the use of a currently registered pesticide in a manner not in compliance with the official state product label. Under normal circumstances, an SLN may be issued when there is no currently registered alternative product available for the purpose. It is normal practice for the registrant to make the application, provide additional label instructions and efficacy data to support the new use pattern.

Experimental Use Permit

Bona fide research personnel who have the appropriate pesticide applicator license may apply for an Experimental Use Permit when wishing to test or research a new product or use an existing product in a new way. The aim of such a permit is to gather data rather than achieve a pest control objective. The size of the area used for treatment must be less than ten acres. Experiments that cover less than 0.25-acres may be exempt. If an area larger than ten acres is required, a federal EUP permit will be needed.

Manufacturer’s Recommendation 2E-E

If a proposed use pattern is not specifically prohibited on the label of a pesticide, the registrant (manufacturer) may issue a 2E-E recommendation allowing the proposed use pattern. These are submitted by the registrant, usually at the request of the agency that requires it.

Commercial Applicator License

Some pesticides are classified as “restricted use”. In order to purchase and use restricted-use pesticides, an operator needs to possess a commercial applicator license issued in the state of Hawai‘i. The tests and licenses are issued by the Hawai‘i Department of Agriculture.

HAWAI‘I DEPARTMENT OF HEALTH

The Clean Water Act (33 U.S.C. §1251 et seq.) (1972) regulates the discharge or potential discharge of pesticides into certain water bodies. Any application of pesticides or herbicides over, or near such waters may require a permit issued by the state Department of Health Clean water Branch. Potentially the Clean Water Act will apply to any pesticide use near Lake Wai‘au.

Hawai‘i Dept. of Health also administers Chapter 343 of Hawai‘i Revised Statutes “Environmental Impact Statements”, which for the purpose of pesticide use on Maunakea regulates requirements for preparing Environmental Impact Statements or Environmental Assessments Per the Statute, The minimum requirement for use of pesticides in the Science Reserve requires is an Environmental Assessment. Pesticide use within or adjacent to buildings and other structures does not fall under these provisions.

HAWAI‘I DEPARTMENT OF LAND AND NATURAL RESOURCES

The UH Managed Lands are located within the state’s Conservation District, Resource Subzone. Application of herbicides and pesticides to an area greater than one acre requires a DLNR-approved site plan (H.A.R. Title 13-5).

OTHER CONSIDERATIONS FOR PESTICIDE USE ON MAUNAKEA

The UH Managed Lands are located within the state’s Conservation District, Resource Subzone. Application of herbicides and pesticides to an area greater than one acre requires a DLNR-approved site plan, contained as an appendix to this document (H.A.R. Title 13-5).

Broadcast herbicide and pesticide use should be avoided in the alpine stone desert above 12,800 ft elevation, within 15 feet of endangered plants, and within a 200-foot buffer around historic properties such as burials.

Pesticide baits in bait stations are generally highly specific and may be used throughout the UH Managed Lands, when used according to label and in consultation with experienced professionals.

The cold, dry conditions of Maunakea slow the microbial breakdown of chemicals to inert compounds. The least persistent formulation among effective options is preferred.

Control Methods

Current control of non-native plants on University managed lands is addressed via management zones. In the Astronomy Precinct and Maunakea Science Reserve, Ranger staff pull and report all non-native species observed. OMKM staff track and report on these activities. Along the road

corridor, below the MKSR, non-native plants are pulled in conjunction with volunteer groups; although few volunteer groups are currently identified which are prepared to hike in the rugged terrain. In Halepōhaku, OMKM staff and volunteer groups conduct semi-monthly volunteer weed pulls targeting all non-native species except grasses. For arthropods, control within facilities is left largely to building owners. Outside of buildings, non-native arthropod control decisions are currently made in consultation with the State DLNR entomologist. Currently control efforts are limited to spot treatment for ants at Halepōhaku and swarm traps for honeybees, all other known non-native species of concern are monitored.

PLANTS

The selection of a control technique is species- and situation-specific, but can generally be predicted by taxa and by the density, size, and area of the plants. Treatment options described below are derived from common practices among conservation agencies in Hawai'i, herbicide labels, and the literature on weed control in Hawai'i⁽²²⁻²⁵⁾.

Cultural Control

Cultural control includes maintaining or restoring undisturbed soil or a ground cover of desirable plants to suppress the establishment of new weeds. As the natural vegetation in most of the MKSR is sparse, cultural control options are limited to avoiding unnecessary disturbance of the natural rock substrate. Controls and monitoring of construction sites, prohibition of off road vehicle use, and requiring visitors to observe established trails and parking areas all support this objective. Ungulates also contribute to soil disturbance and the removal or population control of these species is recommended.

The restoration plan under development for the Halepōhaku area prescribes revegetation with native shrubs and grasses. The "natural" density of vegetation cover for this area is unknown, due to the long history of disturbance and grazing by non-native ungulates. Comparison with other high, dry habitats suggests that it will remain open woodland with sparse bunchgrass and shrub understory. Encouraging native grass and shrubs to occupy prime locations, and limiting disturbance through prevention measures described above, are components of cultural control for this area. In keeping with Hawai'i Administrative Rules (HAR), restoration plans will be developed for the Halepōhaku area and prescribe revegetation with native shrubs and grasses (and any other areas as appropriate).

Mechanical or Manual Control

Mechanical methods include cutting, tilling, disking, or bulldozing with the aid of motorized equipment. These methods all increase soil disturbance and erosion and are not suitable for the Management Area. Manual control methods such as hand-pulling, cutting, and digging or grubbing are more suitable although these methods are slow, labor intensive, and may allow plants to survive and resprout. For many species, the entire plant, including the tap root and fruit or flowers must be dug up and removed from the site for effective control. This limits the effectiveness of manual control to small areas and to plants small enough to be pulled and carried by the average worker.

Weed densities in the Mauna Kea Science Reserve are low enough, at less than 0.1% cover⁽²⁶⁾, that hand pulling is feasible for most species. The time required to pull the occasional weed is

insignificant compared to the time required to travel throughout the MKSR. New species detected in this area are likely to be controlled by hand-pulling.

The nineteen-acre Halepōhaku parcel is more densely vegetated. Monthly removal projects by volunteers have been effective at reducing the cover of certain broadleaf weeds in a portion of this area. Herbicides are nevertheless likely to be required to achieve complete weed control.

Herbicides

Herbicides become necessary when manual/mechanical control is ineffective, or has become inadequate or too costly to continue. The high cost of hauling water up the mountain increases the relative cost of herbicide spraying on UH Managed Lands. Nevertheless, herbicide use is expected to complement manual control in the Halepōhaku area and the Maunakea Access Road from 9,200 ft to approximately 12,000 ft elevation. Herbicides will primarily be used to control established, widespread weeds. Incipient (new) weeds may be sprayed when large, dense, or mature patches of plants are discovered. Treatment, follow-up monitoring, and retreatments will be scheduled to achieve maximum efficacy and to prevent future generations from going to seed. Where continuous vegetation cover must be removed, a restoration plan will be in place to systematically replace the weeds with native grasses and shrubs.

An extensive literature search identified little information regarding special considerations of herbicide use at high elevation, and nothing to indicate that their use on Maunakea will be unusually problematic. Roads and natural areas are maintained in other high elevation (5,000-10,000 ft) sites using the same suite of herbicides recommended in this plan⁽²⁷⁾. All recommended herbicides in this document are low-volatile formulations, designed to prevent rapid evaporation and drift of the active ingredients. Additives are available to further reduce volatilization and drift. While it is recognized that the microbial breakdown of active ingredients is slowed by dry, cold conditions, other herbicides are rapidly broken down through photolytic (sunlight) pathways. The product labels, legal documents which detail use requirements, contain no warnings or prohibitions for use in cold, dry, conditions or at high elevations.

INVERTEBRATES

Control methods for arthropods and mollusks vary depending on the species being controlled or the habitat they occupy. Arthropods are often cryptic or difficult to locate and pest control techniques have evolved to address the variety of life forms and situations that are commonly encountered. Below is a general description of control options for the priority arthropods listed in the previous section.

Ants

Ants can be controlled with baits (often species specific) or application of general purpose insecticides. Baits have the advantage of low pesticide use and target-specificity. In situations where baits are unsuitable for a particular species, or ants are to be excluded from a particular area or structure, residual pesticide “barriers” can be employed.

Ant baits consist of an attractive food item (the bait matrix) laced with a small quantity of pesticide (the active ingredient). Only a portion of worker ants actively forage for food. These forager ants retrieve the baits for consumption by the rest of the colony, either physically carrying the food items, or by carrying the liquid component of the bait in their crop³. As nest mates are encountered, foraging ants will share the contents of their crop, thus spreading the food (and the active ingredient) throughout the colony.

Bait matrices are often different for different species and usually feature a carbohydrate, lipid or protein-based attractant depending on the feeding habits of the target species. Some attractants require the use of an inert carrier to facilitate application. The degree of attraction to a bait matrix determines the level of uptake of the active ingredient.

The active ingredient usually affects all ants in a similar manner regardless of the ant's feeding preferences. However, only a small group of pesticides are suitable for use in ant baits. They must be non-repellent, slow acting and remain toxic even after substantial serial dilution via food sharing. Once an ant begins to become affected by the insecticide, she quarantines herself from the rest of the colony and ceases to share food.

Residual and contact insecticides are less specific and affect all arthropods, including native and non-target species in a similar manner. These are useful for ant species that are not attracted to baits as well as a barrier that prevents further lateral spread.

Wasps

Some wasp species are extremely invasive worldwide. The two most widespread are the German (*Vespula germanica*) and common (*Vespula vulgaris*) wasp. On Management lands the western (*Vespula pensylvanica*) wasp is occasionally observed. All three species are often called "yellowjackets". Many wasp species are social insects, living together in a central nest and working together for defense and food gathering. Unlike ants, a substantial portion of wasps in a single colony are sexually reproductive. This increases the difficulty of controlling these species. A direct treatment of the nest is often the most effective control method. Pesticides can be applied as a dust or aerosol through nest entrances, effectively treating all colony members. Control or treatment of wasp nests should be conducted in late afternoons when all adults have returned to the nest. Due to the extremely aggressive nature of these species and the potential for serious injury to humans, larger nests should be treated by professional pest controllers.

Baits have also been used against some wasp species⁽²⁸⁾, however, successful deployment is only possible during periods of peak protein consumption and this may be difficult on Maunakea.

Spiders

Spiders are a diverse group of arthropods with over 40,000 species known to science. Almost all spiders are predators of other arthropods and invertebrates. Not all spiders spin webs, but many do so. Some species have the ability to survive for months without food as long as a source of water is available⁽²⁹⁾. The effect of pesticides on spiders can be substantially different from the effects of the same compound on insects.

³ All ants are liquid feeders, solid particles are not eaten or digested.

Control methods for spiders focus on treatment of webs and harbors with residual chemicals. Some micro-encapsulated synthetic pyrethroids (eg, lambda-cyhalothrin) appear to be more effective against spiders than flowable or emulsifiable synthetic pyrethroids.

Beetles

Coleoptera (beetles) are one of the most diverse insect groups known to science. Depending on species, they can be detritivores, herbivores, predators, fungivores, parasites, dung-feeders or frugivores. Control methods for beetles are just as diverse as beetles themselves and will need to be developed on a case-by-case basis as new species are encountered.

Horn and Stable Flies

Horn (*Haematobia irritans*) and stable flies (*Stomoxys calcitrans*) (Family: Muscidae) and associated species are usually found in close proximity to farm animals such as cows, horses and dogs. They are also pests of people, adults feeding between 20 and 40 times a day on fresh manure or blood. They bite humans and can be vectors for of diseases and parasites. The larval stages live in dung or rotting material and the adults live in close proximity to their animal hosts. Control methods for horn flies include treatment of the host animal, a visual attractant (box trap), contact pesticides and or insecticides such as synthetic pyrethroids.

Centipedes

The large centipede (*Scolopendra subspinipes*) is one of three centipedes in Hawai'i and the only one of medical importance ⁽³⁰⁾. Although solitary creatures, the females guard any eggs they lay until they hatch. The venom, carried in the jaws, is fast acting and used to suppress prey items. When humans are bitten, the venom can cause a range of reactions from mild swelling of the immediate area to substantial swelling of the entire limb. Large Centipedes prefer dark and moist places for harbor. Control of this species is generally accomplished by spraying potential harbors (cracks and crevices) with a residual pesticide.

Mollusks

Terrestrial mollusks are great at adapting to their environment. The snails slime protects against evaporation, and when the weather becomes too dry, they look for a suitable hiding place. Most slugs will eat detritus including leaves, earthworms, and invertebrates. They can also be carriers of parasites such as *Angiostrongylus cantenosis* (Rat Lung Worm). Control methods for Mollusks include biological control and molluscicide with metaldehyde as the active ingredient.

Site and Species Priorities

When operating within the constraints of resource limitations, decision makers will need to prioritize responses to account for availability of finite human and economic resources. Some sites within the management area have greater cultural, aesthetic or environmental values than others. Additionally, the impacts of some invasive species are likely to be greater than others. Prioritizing which species to control on which site should therefore be determined by both factors. Relative priorities could be assigned to site and species combinations using numerical or non-parametric means (Table 4.1). Thus, a particular species may be a control priority in a high-value habitat and

not a control priority in a low-value habitat. For invasive plants, the Hawai'i Weed Risk Assessment score could be used in lieu of rank order scores.

	Impact of invasive species				
Site priority	Very high (5)	High (4)	Medium (3)	Low (2)	Very low (1)
very high (5)	25	20	15	10	5
high (4)	20	16	12	8	4
medium (3)	15	12	9	6	3
Low (2)	10	8	6	4	2
Very low (1)	5	4	3	2	1

Table 4.1. Notional representation of using rank-orders of site priorities and invasive species impacts to allocate resources. (a commitment to eradicate very high impact species or to preserve very high priority sites might over-ride scoring priorities).

Established invasive plants and their known locations are presented in Table 3.1. Many of the established weeds are grasses and herbs, and are found in dense, mixed-species patches in disturbed areas. This makes a site-specific approach to control more practical than an individual species approach. The site plans that follow describe the general methods to be used to suppress weeds in a defined area, and define the management goal for each area. Individuals or small groups of plants found outside of these areas are considered satellite populations, and may be treated as incipient species with their own control plan.

Some sites have greater environmental, aesthetic or cultural values, determined by their level of ecological integrity, unique habitat type, by cultural significance or aesthetic value. This influences the level and type of control that may be applied to invasive species as well as the control objectives. As a general principle, higher priority sites should be managed to achieve greater levels of cultural significance or values, environmental integrity, aesthetic appeal.

Very High Priority Sites

- Sites with Maunakea silversword (*Argyroxiphium sandwicense spp. sandwicense*)⁽³¹⁾,
- Wēkiu bug (*Nysius wekiuicola*) habitat⁽³²⁾.

Maunakea silversword is an endangered species unique to the Maunakea area. The wēkiu bug, while it has been removed as a candidate for endangered species listing, is emblematic of Maunakea environmental conditions. Any introduced plants or animals in proximity to these species or within their habitat can potentially cause harm to their survival. Additionally, some control methods could

also harm protected species. These sites must be carefully managed to ensure these species are preserved. Selection of control methods must take account of any possible impact on the survival of either Maunakea silversword or wēkiu bugs.

High Priority Sites

- Astronomy Precinct (Maunakea summit),
- Lake Wai'au (not UH managed).

Both the summit and Lake Wai'au are unique habitats with immense cultural, ecological and aesthetic values. Maintaining the integrity of these sites is a high priority. The virtual lack of vegetation at the summit allows for increased use of herbicide control methods as the risk of non-target impacts is very low, although cultural concerns over any management activities are substantial. However, the summit area and the wēkiu bug habitats over-lap and extreme care must be taken with insecticide use which should be restricted to non-wēkiu areas and immediately adjacent to buildings. Invasive species control efforts at Lake Wai'au are conducted in collaboration with the managing agency, however, the Office of Mauna Kea Management recognizes the cultural importance, its attractiveness to invasive arthropods, and the unique ecological nature of this waterbody.

Medium Priority Sites

- Pu'upōhaku crater (not UH-managed),
- Science Reserve.

The broader Mauna Kea Science Reserve (11,228-acres) represents the majority of the entire Management Area and the management of this zone is a central part of the overall management strategy. The Pu'upōhaku crater contains an ephemeral lake that forms part of the Mauna Kea Ice Age Natural Area Reserve, however it is surrounded by lands managed by the Office of Mauna Kea Management. The Office will work in collaboration with the Hawai'i Division of Forestry and Wildlife in the management of invasive species on this site.

Low Priority Sites

- Access Road Corridor,
- Halepōhaku.

Both the Road Corridor and the Halepōhaku sites have lower cultural and ecological importance than the remainder of the Management Area. Both sites experience heavy human use and are impacted by a suite of common weedy introduced plant and animal species. The importance of these sites are more strategic in nature – both being potential vectors for the spread of existing introduced species to other parts of the Management Area. Invasive species management

objectives at these sites are to prevent existing species from spreading rather than maintaining or restoring ecological integrity.

Very Low Priority Sites

- Neighboring lands, access road between the Saddle Road (Daniel K. Inouye Hwy) and Halepōhaku.

The Office of Mauna Kea Management does not manage neighboring lands or the road leading from the Saddle Road to Halepōhaku. However, these areas are potential vectors for the introduction of invasive species. Due to this, the Office maintains an interest in collaborating with neighboring land managers in order to reduce these risks.

Invasive Species Control Plans

Biological surveys conducted over the years have provided baseline inventories of introduced plants and arthropods. The current inventory of plants is fairly complete, while that for arthropods, due to their sheer diversity may never be completely understood.

The inventories show that a limited number of introduced species have been consistently recorded over a number of years, and are therefore considered “established” species. They appear to have naturalized, reproductive populations within the UH Managed Lands. As a community, the plants are abundant, disrupt native plant regeneration, and provide food and habitat for non-native arthropods. Little is known about the life history of much of the arthropod community.

All of the plants, and many of the arthropod species are abundant at lower elevations on Maunakea, and some are found island-wide. Despite the appearance of a stable population, some of these may only exist at high elevations through continuous re-introduction from more a productive population downslope, known as a “rescue effect.” The practical considerations are the same. Most of these species will never be permanently eradicated and are likely to require regular control effort for many years.

ESTABLISHED PLANT SPECIES

A written control plan will be prepared for each Management Zone within the Management Area. Following is a general description of the state of invasive plant species in these zones and recommendations for future control strategies.

Halepōhaku

Halepōhaku is situated just below the treeline, approximately 9,500 ft. in the māmane- (*Sophora chrysophylla*) dominated subalpine woodlands. The subalpine woodlands at Halepōhaku are noticeably more densely vegetated, and more diverse, than the alpine zones. Ground cover is clustered at the base of māmane trees, with considerable bare soil and rock in between. Common

native grasses include Hawai'i bentgrass (*Agrostis sandwicensis*), lovegrass (*Eragrostis spp*), and alpine hairgrass (*Deschampsia nubigena*). None are as common as the invasive needlegrass (*Nassella cernua*) and ripgut grass (*Bromus diandrus*). Common native shrubs include pūkiawe (*Styphelia tameiameia*) and 'āweoweo (*Chenopodium oahuense*). Many native plant species historically recorded in the area are now rare ('ōhelo, *Vaccinium reticulatum*; pilo, *Coprosma montana*) or can no longer be found (makou, *Ranunculus hawaiiensis*; 'a'ali'i, *Dodonea viscosa*), while the list of invasive species has steadily grown ^(2; 26).

Although the endangered palila (*Loxioides bailleui*) has not frequently been observed at Halepōhaku for many years, the area is designated critical habitat for the recovery of the species. Replacement of invasive annual plants with native perennials is expected to support Māmane regeneration through reduced competition for water and nutrients. Successful recovery of all species native to the area may be dependent on the ungulate removal planned by DOFAW following fence completion.

The first priority within the Halepōhaku parcel is to suppress invasive weeds in all high traffic areas, to limit the transport of seeds to the summit by visitors and staff. This is accomplished by designating a weed control buffer around all buildings, walkways, and parking lots in the area. Work will progress outward in stages until a 25-yard buffer, approximately 12.5-acres, is achieved. Weed tolerance levels in the 25-yard buffer are quite low. As this area becomes more manageable, work will intensify in the remaining seven acres of the parcel. Weed removal will be balanced by revegetation work described in the restoration plan, currently under development.

Complete eradication of all weeds at all times is unlikely to be achieved. Acceptable tolerance or threshold levels are measured by plant cover in random plots at least once (ideally twice) per year. Maintenance thereafter will be scheduled to keep weed cover below these tolerance levels. Zero tolerance for mature weeds will be allowed immediately adjacent to thoroughfares. Weed tolerance for the 25-yard buffer is less than 1% cover for mature broadleaf plants, and less than 5% total invasive species cover. Grass cover, including invasive grasses, may be maintained at a higher density to control dust and erosion at the site until alternative cover is established. The management goal is to replace all invasive grasses with native species.

Techniques will include cutting, hand pulling, and applying herbicide, the latter by trained staff or contractors. Work will progress incrementally to allow dense patches of vegetation to be searched for native plants. Rare plants (including "common" native plants that are locally rare) will be documented and visibly marked to prevent accidental impacts.

Herbicide use in the area is expected to be limited to foliar spray of glyphosate (Roundup™) with an added surfactant. The additive is recommended to penetrate leaf surfaces covered with dense trichomes (hairs) typical of weeds in the area. Triclopyr may be added for improved efficacy or used separately on certain weeds. Stubborn or rapidly regenerating weeds may require the use of imazapyr or aminopyralid, formulations with some soil residual activity. Use of these herbicides will be limited in scope and conducted primarily in the initial treatment phase. Herbicides will not be used within five meters of endangered plants.

In 2012, monthly volunteer weed control efforts were organized to begin to remove invasive broadleaf herbs, including fireweed (*Senecio madagascariensis*), telegraph weed (*Heterotheca grandifolia*), mullein (*Verbascum spp.*) from around parking lots and buildings. Grasses were left in place to hold the soil, and to avoid impacts to native species growing amongst the invasive grasses.

Volunteer weed pulls will be moved into the seven-acre, second priority area (areas beyond a 25-yard buffer surrounding facilities). This second priority area consists of approximately 4-acres that separate the Halepōhaku support facilities from the Visitor Information Station; and an additional 1.5-acres due east of the Visitor Information Station. Progress will be gradual to allow time for native species to gain a foothold in the cleared areas, a process which may be aided by broadcast seeding and outplanting common native species, according to the restoration plan under development. OMKM also has concurrence with DOFAW to conduct manual weed control inside the DOFAW managed 2.25-acre silversword enclosure. The volunteer program provides a meaningful, hands-on experience on the mountain for members of the Big Island community, builds relationships, and increases awareness of the OMKM mission and program areas.

The 1.5-acre construction staging area is outside of the 25-yard buffer. This staging area is to be treated as a quarantine area with all introduced plants removed and the site treated prophylactically with residual pesticides to prevent establishment of any arthropods that may inadvertently be carried with construction supplies.

Summit Access Road

The lower portion of Summit Access Road traverses the alpine shrubland. Roadsides are dotted with the native nohoanu (*Geranium cuneatum* ssp. *hololeucum*), pāwale (*Rumex giganteus*) and pūkiawe (*Styphelia tameiameia*), and as well as introduced fireweed (*Senecio madagascariensis*), sheep sorrel (*Rumex acetosella*), and common mullein (*Verbascum thapsus*). Plant densities decline rapidly with increasing elevation through the alpine grassland (grass desert) and alpine stone desert. The upper portions of the road are barren, with occasional native na'ena'e (*Dubautia* spp.), pūkiawe, native grasses, or introduced species.

While OMKM has authority to manage only the road and the easement to the east side of the road for much of its length, management of weeds on only one side of the road is clearly impractical. OMKM is to collaborate with the Natural Area Reserve management to jointly monitor and control weeds throughout the shared length of road.

The purpose of weed control along the access road is to prevent establishment of new weeds, and to halt the progression of established weeds to higher elevations. The road and 400 yard easement together comprise 700-acres, an area that may be too large to keep weed free. The majority of weeds are likely to be found close to the road. Roadsides are ideal weed establishment sites, due to regular disturbance from road grading and traffic. Propagule pressure is high, with weeds hitchhiking on every variety of vehicle. Seeds that have successfully attached to vehicles may be shaken off as the vehicle traverses the unpaved portion of road eg. attached to dried soil that

becomes detached from vibration. Successfully established roadside weeds reproduce to become hitchhikers once again and are transported upslope.

The primary objective for this Management Zone is the suppression of weeds within ten yards of the formed roadway. Work will progress from high to low elevation. As satisfactory control of established weed species is achieved in this area, the control zone will be enlarged to include additional lands further from the road. Increasing distance from the road is expected to provide a diminishing return on effort. Despite relatively low weed densities, it is unlikely that the entire width can be regularly maintained.

Weeds will be hand pulled where feasible (at high elevation), and sprayed with herbicide as the size and density of patches increase (below the Science Reserve). Herbicide options are the same as those presented for use in the Halepōhaku area. Glyphosate sprays with an added surfactant are generally efficacious for the known weed species in the. Imazapyr and aminopyralid have some residual action and may be used to decrease treatment frequency.

The Access Road has mostly been formed in a manner to reduce the grade to a level suitable for four wheel drive vehicles. This results in a series of side-cut and raised road sections. This presents operational challenges to weed control. The steep, loose sides cannot be safely traversed to cut, pull, or spot-spray individual plants. At lower elevations, invasive and native species are thickly interspersed, making broadcast spraying from a truck difficult. Weed control in these areas will require resources to develop practical control techniques. OMKM will work with BIISC, the University of Hawai'i agricultural extension program (CTAHR), and the Hawai'i Department of Transportation to develop effective and appropriate procedures.

The Mauna Kea Science Reserve (MKSR)

The MKSR includes one alpine plant community, the alpine stone desert from approximately 11,000 ft to the summit, 13780 ft ⁽³³⁾. Perhaps due to historical grazing by introduced ungulates, little distinction can currently be observed between the two alpine plant communities described by Mueller-Dumbois and Fosberg⁽³⁴⁾, alpine grass desert and alpine stone desert), other than an incrementally greater density of plants at the lower elevations ⁽²⁶⁾. The entire MKSR is characterized by very low densities of two native grasses, Hawaiian bentgrass (*Agrostis sandwicensis*) and pili uka (*Trisetum glomeratum*), the shrubs pūkiawe (*Styphelia tameiameia*) and 'ōhelo (*Vaccinium reticulatum*), and occasional ferns, including Douglas' bladderfern (*Cystopteris douglasii*, a candidate endangered species) and kalamoho (*Pellaea ternifolia*). Perhaps more common than any vascular plants, are mosses, lichens, and algae growing in protected sites. 'Āhinahina (the Maunakea silversword, *Argyroxiphium sandwicense* ssp. *sandwicense*), a federally endangered species, is found within fenced units in this area.

A few established invasive plants are dispersed at low densities throughout the UH Managed Lands. Hairy cat's ear (*Hypochaeris radicata*), for example, is likely to be found in sheltered sites throughout the MKSR. Staff recently found approximately one plant for every mile hiked in the MKSR. Regular surveys of the entire 11,288-acre MKSR to remove plants at that density may be

impractical. Control of widespread, low density species is therefore focused at sensitive sites, which include historic properties and rare plant locations. These sites are regularly monitored by trained archaeologists and biologists, respectively. Like any visitors, scientists may also inadvertently introduce invasive species. By including weed control with their scheduled activities, OMKM can detect and control weeds at more than 263 well-distributed sites, traveling over a large portion of the MKSR without adding a significant level of disturbance. This approach mimics the Special Ecological Area or Weed Control Area Buffer systems used by other conservation agencies in Hawai'i (4; 22; 35). It may be unique, however, in using historic properties, in addition to high value natural resources, as foci for weed control.

The Astronomy Precinct

All of the Astronomy Precinct is within the alpine stone desert. Certain invasive plant species, including hairy cat's ear (*Hypochaeris radicata*), fireweed (*Senecio madagascariensis*) and rescue grass (*Bromus catharticus*), are found more commonly in cracks, drainage ditches, and roadsides within the astronomy precinct than elsewhere in the MKSR⁽²⁶⁾. It is unknown whether the frequency of invasive plants is due to higher rates of introductions or a greater variety of sheltered sites, or, likely, both.

Invasive plants in the vicinity of roads and observatories remain sufficiently sparse that they can be removed by regular hand-pulling. Ranger patrols already accomplish this task as part of their routine, and report the species, and number of invasive plants pulled in their daily ranger report. Although the effort has so far been limited to fireweed, training is planned to increase competency to distinguish the limited number of native and invasive species. Distinct work areas will be clearly defined and named to improve staff ability to schedule and treat all developed areas known or likely to have invasive weeds.

ESTABLISHED ARTHROPODS

Unlike invasive plants, control methods for invasive arthropods are often species-specific and little commonality exists between the management approaches for different species. For this reason, arthropod management plans must be prepared by species for the entire Management Area. Some commonality between control methods for species found in and around structures may exist, and these may be different from control methods in the natural environment. For this reason, the management plans may outline different approaches for these two habitat types.

A total of 209 arthropods have been detected within the Management Area as a result of various invertebrate surveys ⁽³⁶⁻⁴⁵⁾. Of these, many pose little or no threat to human health or the environment. However, fifteen species pose threats to human health and safety and are closely associated with humans (Table 4.2). These species will be controlled within and near facilities (buildings and other structures) wherever possible. Thirty four arthropod species have been classified as low-level threats to ecosystems (Table 4.3). Of these, seventeen species (mostly very small wasps) are dependent on host plants which themselves are introduced. As these host plants

are controlled, the associated arthropods will not be able to survive. The remaining species are spiders (11 species) and beetles (6 species) – mostly common “weedy” species that are globally ubiquitous and widespread. Controlling these species in the environment is difficult and generally the non-target impacts of control methods are an unacceptable compromise. These species will be controlled within and near facilities (buildings and other structures) wherever possible through a general pest control program.

Table 4.2. Arthropod species detected within the Management Area that pose a human health risk.

Common Name	scientific name	Control Type	Feasibility of control
German cockroach	<i>Blattella germanica</i>	sanitation, pesticides or baits	Good
American cockroach	<i>unknown</i>	sanitation, pesticides or baits	Good
non- biting midge	<i>Chironomus sp.</i>	sanitation (remove water sources)	Good
midge	<i>unknown</i>	sanitation (remove water sources)	Good
mosquito	<i>unknown</i>	sanitation (remove water sources)	Good
honey bee	<i>Apis mellifera</i>	swarm traps	Good
European paper wasp	<i>Polistes dominus</i>	traps, pesticides	moderate
red brown paper wasp	<i>Polistes olivaceus</i>	traps, pesticides	moderate
western yellow jacket	<i>Vespula pensylvanica</i>	traps, pesticides	moderate
hornet/wasps	<i>unknown</i>	traps, pesticides	moderate
blood feeding horn fly	<i>Haematobia irritans</i>	traps, pesticides	Low
blood feeding horn fly	<i>Stomoxys calcitrans</i>	traps, pesticides	Low
house fly	<i>unknown</i>	traps, pesticides	Low
fly	<i>unknown</i>	traps, pesticides	Low
biting midge	<i>Forcipomyia spp.</i>	testicides	Low

Table 4.3. Arthropod species detected within the Management Area that pose an environmental threat.

Common Name	Scientific name	Control Type	Feasibility of control
braconid wasp	<i>Apanteles spp.</i>	remove host plants	low
braconid wasp	<i>Bracon spp.</i>	remove host plants	low
braconid wasp	<i>Chelonus blackburni</i>	remove host plants	low
braconid wasp	<i>Ontsira palliates</i>	remove host plants	low
braconid wasp	<i>Unknown</i>	remove host plants	low
funnel weaver	<i>Unknown</i>	sanitation, pesticide	low
sac spider	<i>Unknown</i>	sanitation, pesticide	low

sac spider	<i>Meriola arcifera</i>	sanitation, pesticide	low
ground spider	<i>Urozelotes rusticus</i>	sanitation, pesticide	low
stealthy ground spider	<i>Unknown</i>	sanitation, pesticide	low
sheet web spider	<i>Erigone spp.</i>	sanitation, pesticide	low
sheet web spider	<i>Lepthyphantes tenuis</i>	sanitation, pesticide	low
jumping spider	<i>Unknown</i>	sanitation, pesticide	low
cobweb weavers	<i>Unknown</i>	sanitation, pesticide	low
spider	<i>Unknown</i>	sanitation, pesticide	low
drugstore beetle	<i>Unknown</i>	pesticides	low
ground beetle	<i>Agonum muelleri</i>	pesticides	low
ground beetle	<i>Laemostenus complanatus</i>	pesticides	low
ground beetle	<i>Trechus obtusus</i>	pesticides	low
ground beetle	<i>Unknown</i>	pesticides	low
redlegged ham beetle	<i>Necrobia rufipes</i>	pesticides	low
ichneumonid wasp	<i>Calliephialtes grapholithae</i>	remove host plants	low
ichneumonid wasp	<i>Diadegma blackburni</i>	remove host plants	low
hover fly parasite	<i>Diplazon laetatorius</i>	remove host plants	low
ichneumonid wasp	<i>Hyposoter exiguae</i>	remove host plants	low
ichneumonid wasp	<i>Ichneumon cupitus</i>	remove host plants	low
ichneumonid wasp	<i>Ichneumon laetus</i>	remove host plants	low
ichneumonid wasp	<i>Ichneumon spp.</i>	remove host plants	low
ichneumonid wasp	<i>Meteorus purpuripennis</i>	remove host plants	low
ichneumonid wasp	<i>Pristomerus hawaiiensis</i>	remove host plants	low
ichneumonid wasp	<i>Trathala flavoorbitalis</i>	remove host plants	low
ichneumonid wasp	<i>unknown</i>	remove host plants	low
leaf cutting bee	<i>Megachile timberlakei</i>	remove host plants	low
ghost ant	<i>Tapinoma melanocephalum</i>	baits	high
white-footed ant	<i>Technomyrmex albipes</i>	pesticide or baits	high
plagiolepis ant	<i>Plagiolepis alluaudi</i>	pesticide or baits	high
cardiocondyla ant	<i>Cardiocondyla kagutsuchi</i>	pesticide or baits	high

HIGH-PRIORITY ARTHROPOD THREATS

Three high-priority arthropod pest species (all ants) have been detected within the Management Area: *Tapinoma melanocephalum*, *Technomyrmex albipes*, *Plagiolepis alluaudi*, and *Cardiocondyla kagutsuchi*. The locations these species have been detected at are shown in Figure 4.2. *T. albipes* has recently been reclassified, and most taxonomists now believe “*albipes*” is a group of four distinct, closely related species (*vitiensis*, *albipes*, *difficilis* and *pallipes*). The most common of these on Hawai’i island is *T. vitiensis*. The only established ant in the Management Area is *Cardiocondyla kagutsuchi* at Halepōhaku, all other ant species have only been detected in single instances and not found in established populations.

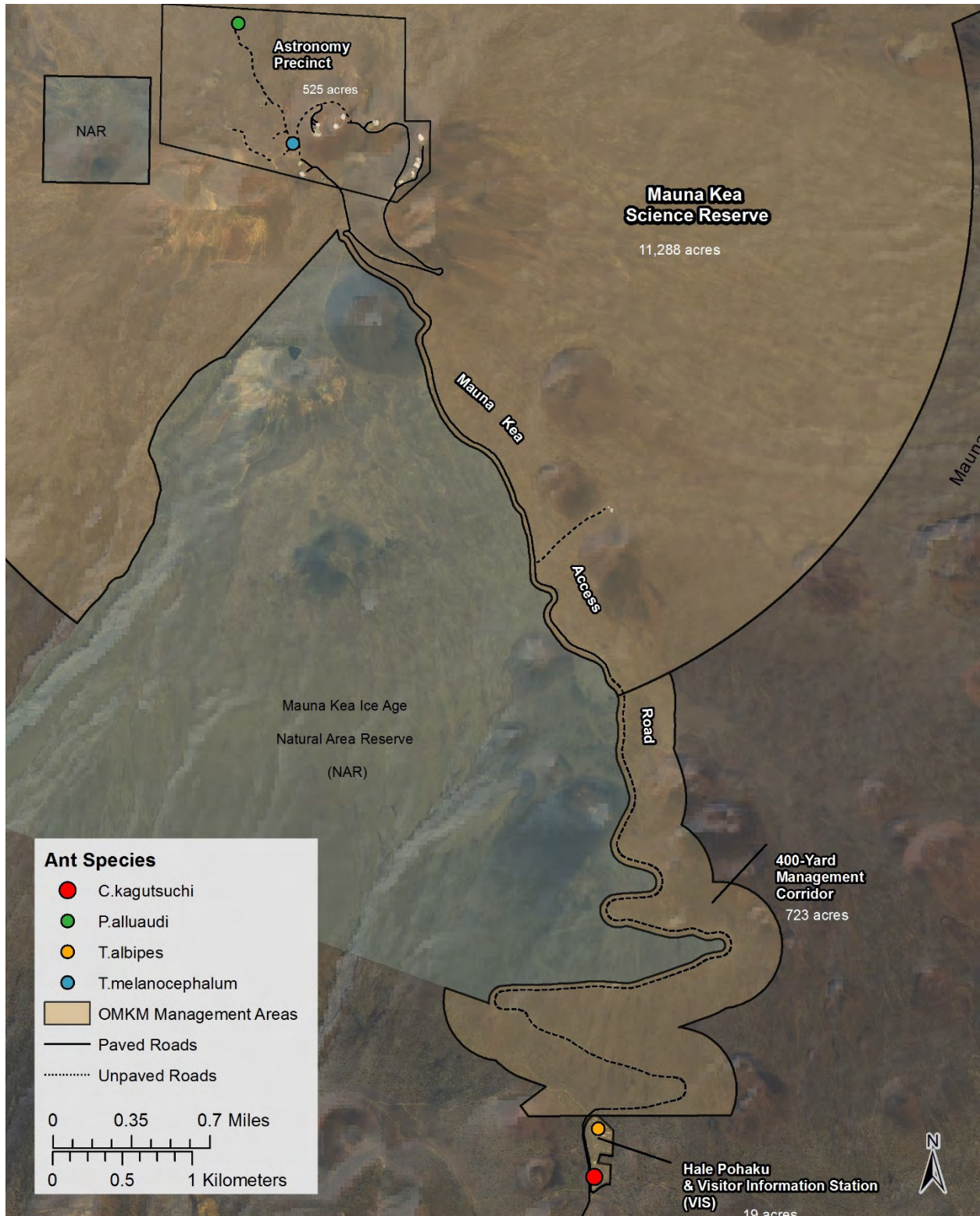


Figure 4.2. Ant detections in the Management Area.

Each established species will require a separate management plan as control methods differ substantially between species. *Tapinoma melanocephalum* a tropical structural pest, attracted to baits containing carbohydrate attractants, while *C kagutsuchi* and *T "albipes"* are not attracted to a particular bait type.

Section 5. Rapid Response

Background

The Mauna Kea Science Reserve and Halepōhaku are 11,288-acre and 19-acre (respectively) areas of land leased by the University of Hawai'i from the State of Hawai'i for use as a scientific complex. Management is guided by the 2009 Mauna Kea Comprehensive Management Plan (2009) which provides the policy framework for the responsible stewardship and use of University-managed lands on Maunakea through to 2020. The Comprehensive Management Plan addresses the overall management of cultural, natural, research and recreational values of the precinct. The management policies for the natural values of the Mauna Kea Science Reserve are outlined in the Mauna Kea Natural Resources Management Plan (2009) which forms a component plan of the Comprehensive Management Plan.

The following agencies have jurisdiction, responsibility or roles relating to the detection and management of invasive species in the Mauna Kea Science Reserve and Halepōhaku:

- **The Office of Mauna Kea Management** has overall responsibility for managing the Mauna Kea Science Reserve subject to approval by Hawai'i Department of Land and Natural Resources,
- **The University of Hawai'i** leases the Management Areas from the State of Hawai'i (or holds easements), identifies policy through the Master Plan (2000), and provides institutional support to OMKM,
- **The Department of Lands and Natural Resources** is the land owner and reviews all land use proposals to determine the appropriate level of permitting, approve plans or permits, or refer the proposal to the Board of Land and Natural Resources for action,
- **Hawai'i Division of Forests and Wildlife** provides technical advice on issues, manages the Mauna Kea Ice Age Natural Area Reserve, and has regulatory authority for wildlife,
- **The Mauna Kea Management Board** is a volunteer, community-based entity with a sustained direct voice for the management, and approve OMKM projects and plans, and
- **Hawai'i Department of Agriculture Pesticides Branch** administers the state pesticide regulations which govern the use of pesticides in the state of Hawai'i.

Outline

This section contains a detailed emergency response plan (ERP) for incursions of invasive arthropods or plants discovered in the Maunakea management area. The document is divided into five parts which correspond to the different stages of a response:

Pre-incursion planning – The general level of preparedness recommended for the Office of Mauna Kea Management is described in this section. It includes the tasks that should be undertaken before an incursion is detected.

Initial detection and response – This section outlines the logical steps and lines of authority for the initial investigation and the process for decision making.

Guidelines for the initial delimiting survey – Once an incursion has been detected, it is important to determine how large the pest population is. Often a single detection is followed by discovery of other populations of the same species. The extent of the invasion is an important factor in deciding the best course of action and provides the basis for estimating budgets and resources needed to manage the situation.

Elements of a management plan – This section describes the essential elements of a plan to manage the new incursion.

Organizational structure and reporting – The organizational structure and reporting relationships of staff engaged in a response are listed in this section.

This document should be reviewed before, during and after an incursion.

Pre-Incursion Planning

There are four important issues that need to be addressed before an exotic species incursion is discovered:

LEGISLATIVE POWER TO ACT

The DLNR-approved Mauna Kea Master Plan (2000) and Mauna Kea Comprehensive Management Plan (2009) identify the University's responsibilities to address invasive species issues, as does the 1968 General Lease. Additional law and policy information is available at <http://dlnr.hawaii.gov/hisc/info/policy/>. In addition, Maunakea is specifically identified as not exempt from State of Hawai'i requirements to prepare an Environmental Assessment. ([http://oeqc.doh.hawaii.gov/Shared%20Documents/Environmental Council/Exemption Lists By Department/State Agencies/University-of-Hawaii-2001-03-14.pdf](http://oeqc.doh.hawaii.gov/Shared%20Documents/Environmental%20Council/Exemption%20Lists%20By%20Department/State%20Agencies/University-of-Hawaii-2001-03-14.pdf)). This is interpreted to mean the Science Reserve. Hawaii Administrative Rules for lands zoned as Conservation identify requirements for obtaining plans or permits.

The Office of Mauna Kea Management should ensure that it has the powers needed to act promptly on the discovery of a new invasive species, including use of appropriate pesticides or removal methods, power to enter any infested area, and appropriate certifications for application personnel.

REGISTRATION AND PERMITS TO APPLY CONTROL CHEMICALS

Registration of pesticides and applicators is the responsibility of the Hawai'i Department of Agriculture (HDOA) and the federal Environmental Protection Agency (EPA). Any pesticide used in the United States must be registered with the EPA under the Federal Insecticide, Fungicide and Rodenticide Act. Any EPA registered product must also be registered under state regulations before it can be legally used in Hawai'i. Office of Mauna Kea Management field staff should be properly trained in the safe and effective use of any pesticide likely to be used in an emergency

response. Per the Mauna Kea Natural Resource Management Plan, pesticide application will be done by individuals possessing a pesticide applicator license issued by the Hawai'i Department of Agriculture Pesticides Branch.

AVAILABILITY OF CHEMICALS AND APPLICATION EQUIPMENT

Appropriate chemicals, application equipment and personal protective wear (gloves, masks etc.) should be on-hand in readiness for a rapid response. These items should be stored in appropriate conditions and product expiry dates checked regularly to ensure they are ready for use. Sufficient stocks should be on hand to treat a minimum of 1-acre infested by any target species. Areas below the Science Reserve boundary requiring treatment larger than 1-acre require additional DLNR approval, providing additional time to obtain resources (HAR §13-5).

ACCESS TO EMERGENCY FUNDS

In many cases, the discovery of a new invasive species will require a response and resources not budgeted for in normal operating funds. The Office of Mauna Kea Management will request, from the University of Hawai'i, additional funds and human resources in the event of a new incursion.

Initial Detection and Response

When a suspected invasive species is reported, the generic response to this detection is outlined in Figure 1. During this part of the response, the Natural Resource Program (NRP) manager of the Office of Mauna Kea Management seeks to confirm the identity of the species and obtain an initial report of the extent of the infestation. With this information, the NRP manager will decide whether to involve the Emergency Response Management Committee (ERMC).

Before the ERMC meets to discuss the incursion the NRP manager should begin a delimiting survey and restrict movement of for risk items leaving the infested area. These risk items include potted plants, soil and aggregates, items that have been in contact with the ground, produce, hay or wood shavings (a common spill containment berm material), mulch and building supplies, earthmoving equipment and other vehicles. The risk items list may need to be revised depending on the species that has been detected and/or other site-related factors such as activities being conducted in the infested area.

THE EMERGENCY RESPONSE MANAGEMENT COMMITTEE

The ERMC is a standing committee with oversight of invasive species detections for Maunakea. The committee advises and informs the Maunakea Management Board, has powers to authorize temporary resources for immediate response activities and makes decisions on how to proceed. A flowchart showing the flow of information on discovery of a new invasive species is shown in Figure 5.1, and options that the ERMC will consider is shown in Figure 5.2. The ERMC shall be comprised of the following persons:

1. Chairperson, Mauna Kea Management Board
2. Members of the Maunakea Management Board as required

3. Delegate, Office of Coastal Conservation Lands (Department of Lands and Natural Resources)
4. Branch Manager, Division of Forestry and Wildlife (or delegate)
5. Representative, Kahu Kū Mauna
6. Coordinator, Big Island Invasive Species Committee (or delegate)
7. Office of Mauna Kea Management Natural Resource Manager [non-voting]
8. A specialist or specialists of the new invasive organism [non-voting]
9. Other persons or advisors as deemed necessary by the chair [non-voting]

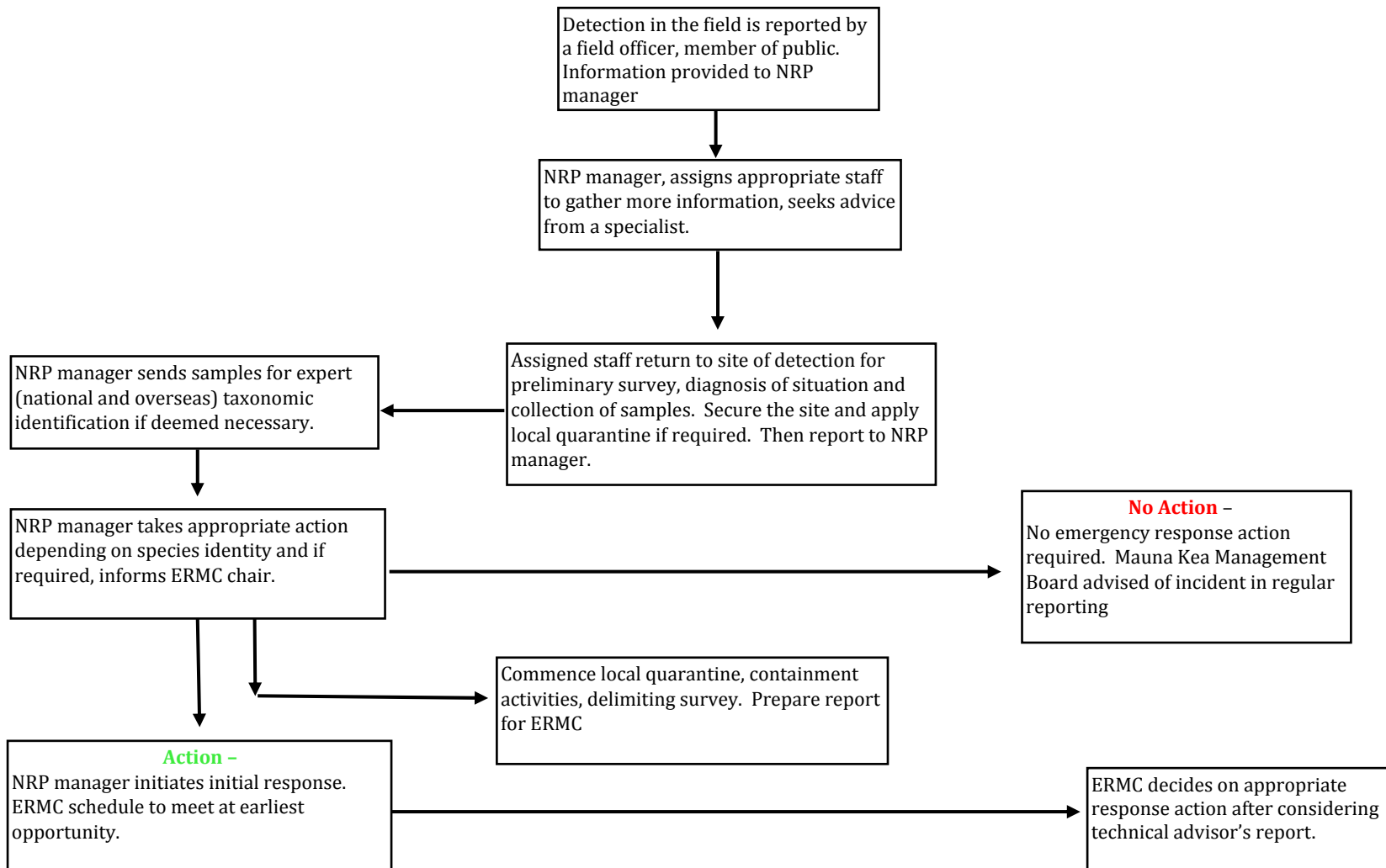


Figure 5.1. Generic response to a suspected invasive species detection.

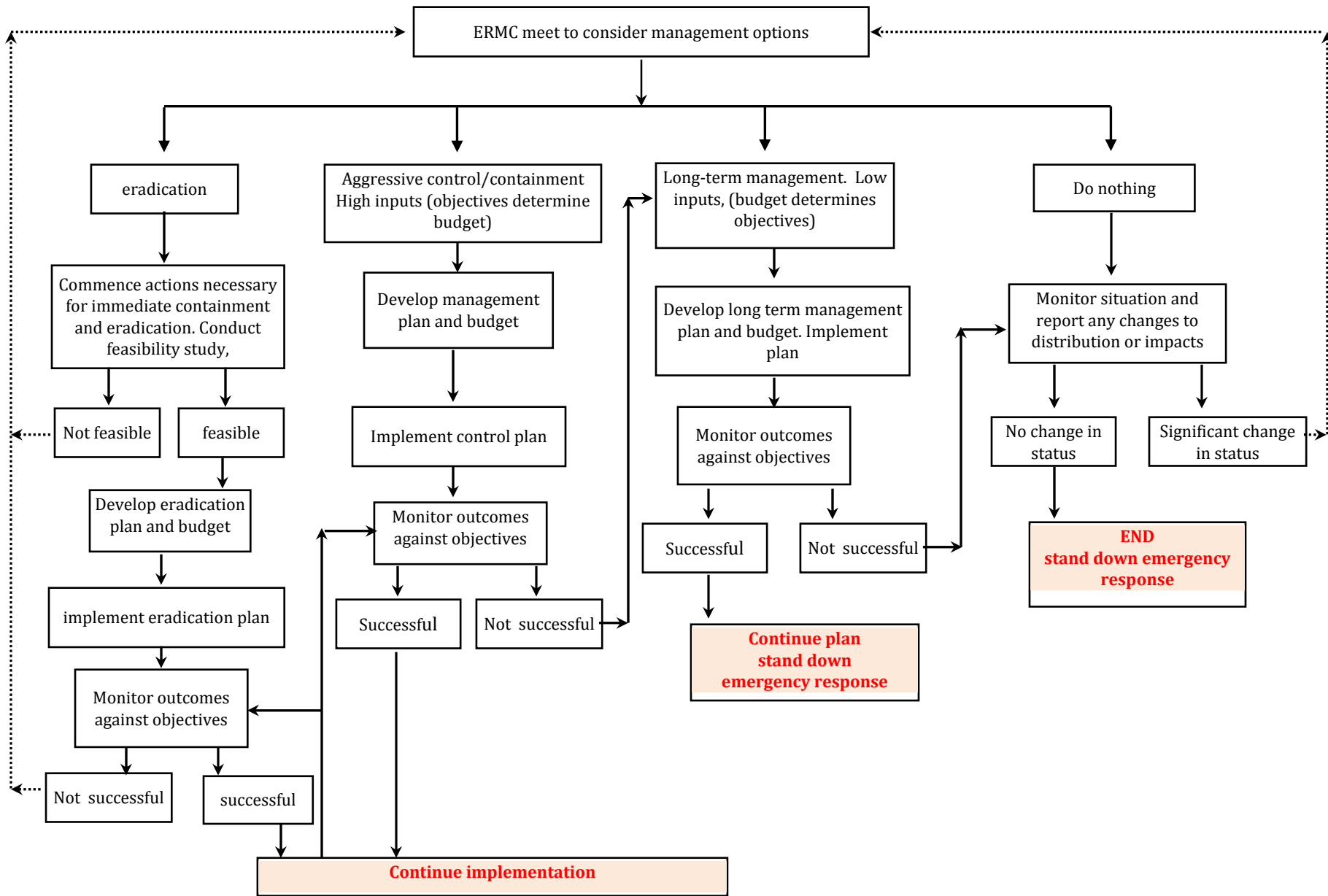


Figure 5.2. Decision flowchart used by ERMC to decide appropriate course of action and monitor outcomes

ROLES AND RESPONSIBILITIES

A brief outline of the functions and responsibilities of persons involved in an emergency response is listed in the table below.

Table 5.1. Roles and responsibilities of persons involved in the emergency response

POSITION	ROLES AND RESPONSIBILITIES
University of Hawai'i	<ul style="list-style-type: none"> • Provides funding for the Emergency Response Plan.
Mauna Kea Management Board	<ul style="list-style-type: none"> • Overall approval of the program.
Emergency Response Management Committee (ERMC)	<ul style="list-style-type: none"> • Discusses recommendations from the Technical Adviser (TA) after delimiting survey and decides on further action; • Recommends overall strategy to the Mauna Kea Management Board; • Appoints Operations Manager and Field Controller;
Natural Resource Program manager	<ul style="list-style-type: none"> • Liaison for Office of Mauna Kea Management; • Typically Initiates response actions
Specialist appointed by and reporting to ERMC	<ul style="list-style-type: none"> • Collects samples and organizes identification of samples; • Collects information.
Operations Manager appointed by Mauna Kea Management Board on recommendation of ERMC	<ul style="list-style-type: none"> • Reports to ERMC ; • Manages day-to-day finances; • Oversees field operations; • Checks resource requirements; • Selects and appoints the response team(s); • Briefs and trains response team(s) and Field Controller together with Technical Adviser.
Technical Adviser <ul style="list-style-type: none"> • appointed by ERMC; • reports to nobody to make sure that advice remains objective; • located as required; • has to be a recognized expert on the 	<ul style="list-style-type: none"> • Conducts delimiting survey; • Submits report including response options, recommendations and tentative budgets to ERMC; • Briefs and trains response team(s) and Field Controller together with Operations Manager; • Provides technical advice to ERMC, Operations Manager, Field Controller, operational teams;

particular species or taxon.	<ul style="list-style-type: none"> Periodically monitors operations.
Finance Officer	<ul style="list-style-type: none"> Responsible for administration and finance.
	<ul style="list-style-type: none"> reports to Operations Manager.
Field Controller	<ul style="list-style-type: none"> Logistics; Day-to-day control of field operations; Liaises with district staff and stakeholders.
	<ul style="list-style-type: none"> appointed by ERM on recommendation of Operations Manager; located on site full time; reports to Operations Manager;
Field Teams	<ul style="list-style-type: none"> Field activities such as surveys.
	<ul style="list-style-type: none"> appointed by Operations Manager; report to Field Controller.

The Specialist

OMKM rangers are usually the first to investigate a possible incursion after it is reported. It is the role of the specialist to collect specimens for identification, dispatch them to a recognized expert and gather information on the incursion and the species detected for the NRP manager.

Before leaving to investigate the suspect incursion, the Specialist should seek confirmation of the powers available to him or her, specifically when it pertains to site entry, quarantine directions and preventing the movement of risk items.

Collecting Specimens

The first step in managing a possible invasive species incursion is to know exactly which species has been detected. This means obtaining specimens and having them identified by an appropriate taxonomist and confirmed by a reliable institution. Guides to collecting specimens are appended.

Secure the Scene/Containment

Invasive species can spread quickly from one site to another by human-mediated means. Insects, plant seeds etc. can be concealed in produce, potted plants and other risk items which are transported by people to a new location. Preventing further spread at this stage of an incursion is very important. If it can be established that only a small area is infested, preventing public access to the entire site is a very good solution. If the infested site is larger, the Specialist should ensure that people living or working within the infested area do not move risk items to other locations. Risk items should include the following:

- Soil, gravel, aggregates or other landscaping material,
- Any item that has been in contact with soil for more than 24 hours,
- Potted plants, mulch, hay, firewood, thatching and other building materials,

- Earthmoving machinery.

The risk items list may need to be revised depending the species that has been detected and/or other site-related factors such as industries or activities being conducted in the infested area. For example, ant colonies will disperse if the colony is disturbed. The Specialist should ensure that people living or working in or near the infested area do not, disturb, interfere or attempt to treat the insects or plants. If the infested area is small, it may be demarcated with “caution” or “quarantine” tape.

Gather Information

After returning from the initial investigation, the specialist should prepare a short situation report for the NRP Manager which should include the following information as a minimum:

- the result of the identification,
- picture(s) of the invasive species,
- date and details of first report,
- size and location coordinates of the infested area,
- if possible, an indication as to how the organism may have reached the area,

Additionally, the specialist should compile available information (reports, journal articles, etc) about the species including:

- potential impacts in terms of:
 - economic impacts,
 - social (including human health) impacts,
 - cultural impacts,
 - environmental impacts and biodiversity.
- expected cost of export treatments,
- known control measures and inadvertent impacts.

Once the species identity has been verified, a decision needs to be made on how to progress. The final decision on further action lies with the ERMC. If the invasive species is likely to cause unacceptable impacts, the Chairperson appoints a Technical Adviser to conduct a delimiting survey and mobilizes the necessary funds. (Please note that the Specialist could fulfill this function if sufficiently qualified).

The NRP Manager establishes quarantine restrictions as required, and in close collaboration with the ERMC should brief the Mauna Kea Management Board on the incursion. Once all parties have been briefed, the ERMC should notify staff working within the Management Area of the occurrence of the new invasive species and what to look for and how, who and where to report to. The ERMC should also appoint a communication specialist to develop a communication strategy.

The Technical Advisor

The NRP Manager, in consultation with the ERM, may proceed with an emergency response or decide to take no further action. If proceeding with a response, a Technical Advisor will be appointed by the ERM with advice from NRP Manager. The Technical Advisor's role is to delimit the infestation, advise the NRP Manager on trace-forward and trace-back activities, and prepare a draft management plan. The Technical Advisor does not recommend a course of action as this decision is made by the ERM. Rather he or she advises on the technical merits of proposed courses of action.

Delimiting Survey

The immediate task of the Technical Advisor is to plan and implement a delimiting survey. Standardized surveillance methods have been developed and are appended. The delimiting survey is carried out by a survey team composed of the Technical Advisor, the Specialist, available field officers from the Office of Mauna Kea Management and the Field Officer who initially reported the species. The size of the survey teams will depend on the expected area to be surveyed. Additionally, one or more staff from the appropriate quarantine agency should be on hand specifically to coordinate and implement trace-forward and trace-back activities. The communication specialist should be involved in the delimiting survey and oversee media and public communication when necessary.

The objectives of the delimiting survey are:

- Establish the borders of the infested area,
- Gather information for deciding what actions should follow,
- To advise staff on trace-forward and trace-back activities in order to determine if there are more infested areas, and
- To determine resources needed.

The Technical Adviser ensures that all items required for the survey are available, such as:

- Emergency response plan,
- A map of the area,
- Notebooks, pens, pencils, markers,
- Digital camera, GPS units, radios with enough batteries,
- Field record sheets,
- Equipment: brush, pocket knife, spade, hand lens, specimen bottles, plastic bags in various sizes, 70% alcohol solution, torch, gloves; aspirator, forceps, and
- First aid kit.

The survey starts from the area where the incursion was reported. Actions included are to:

- identify potential users of the site, inform them of the situation, discuss actions to take and seek their cooperation,

- establish exactly how and when the new species reached the area,
- monitor the speed of dispersal,
- map boundaries and estimate size of the infested area,
- identify soil, aggregates, machinery, plants, plant products, or other articles whose movement out of the infested area would need to be regulated in the containment of the species,
- identify and notify the owners of these materials, machinery, plant products, or other articles,
- assess the possibility of containing the new invasive species and prevent further spread,
- identify how and where infested items and/or products could be treated or disposed of,
- take pictures of the new species, including affected plants and areas,
- through the communications specialist, inform appropriate authorities and stakeholders,
- recommend local staff who would need to be part of further actions,
- assess the feasibility, costs and possible problems of containing, eradicating and managing the new species.

As soon as practical, and in consultation with the other team members, the Technical Adviser completes a survey report with the addresses of all stakeholders as an annex and distributes it to both the survey team and the ERM members. The survey report should include: names of areas surveyed, area affected (extent of infestation), description of land use type, accessibility, include maps, photographs, density of infestations and land tenure.

The survey report also includes response options, recommendations and tentative budgets. The Report should not recommend a particular course of action but outline options available. The ERM makes the decision on what options to take.

The ERM will, based on the Report decide the response actions:

1. If the species cannot be eradicated in the infested area: containment within the infested area and surveillance in endangered areas,
2. If the species can potentially be eradicated in the infested area: containment within the infested area and surveillance in endangered areas, followed by eradication in the infested area if the first step was successful.

Draft Management Plan

The Technical Adviser will develop a draft management plan and budget for the response decided by the ERM. The Chairperson convenes a meeting of the ERM to discuss the Technical Adviser's report within a week of report submission when the committee decides on a course of action. After approval by ERM, the Technical Adviser finalizes the management plan and budget for approval by the ERM, in consultation with the Finance Officer and NRP Manager.

The management plan should include the following components:

1. A surveillance plan,
2. A plan for treatment and eradication including anticipated timeframe to eradication (if needed),
3. A communications strategy,
4. Specifications for movement controls of risk items out of the infested area.
5. The methods to be used for monitoring progress and declaration of area freedom,
6. A budget,
7. Recommendations for operational research (if needed); and
8. An organizational plan, suggested including time tables.

SURVEILLANCE PLAN

The Surveillance Plan should include the following

- Specification of plants, plant products, and other risk items that could be hosts or carry the invasive species,
- A list of surveillance sites selected on the advice of the Technical Adviser,
- Measures that achieve cooperation from users of the infested site,
- Instructions on how to:
 - survey an area,
 - record data,
- State who would do the actual surveillance,
- List of required surveillance equipment (preferably locally available),
- Instructions for collecting and preserving suspect specimens for identification by a local specialist,
- Define further action if suspicious specimens are found,
- A surveillance schedule, and
- Starting date for monthly reviews of the operation.

The surveillance plan should have an information file on the new species and the relevant part of any legal provisions attached.

TREATMENT

The treatment plan should contain the following:

- A definition of the infested area: which plants, plant products, or other articles need to be treated, destroyed or disinfested,
- Measures that achieve cooperation from site users and owners of possibly infested plants, plant products or other articles in the infested area,
- A list of required equipment (preferably locally available). Stockpiles of pesticides for treatments that can be used and replaced,
- Consideration should be given at an early stage to the registration of any pesticides that are not already registered or use patterns not covered by existing labels,
- Contain instructions on how to treat, disinfest or destroy risk items,
- Action if suspicious specimen are found,

- Specify under what conditions restitution may need to be paid for destruction of infested items
- Establish work schedules,
- Indicate the duration of treatments,
- Specify the period of time without new detections that has to elapse before the species can be declared eradicated. (Usually this is two years, but may be longer for plants with long-lived seed banks),
- Establishment of an operational control center or use an already established facility; and
- Starting date for monthly reviews of the operation.

The eradication plan has the file on the new species and the relevant part of the legal provisions attached.

COMMUNICATIONS

A communications strategy will need to be developed by a communications specialist and should address the following issues:

- Lines of communication for operational staff, the Mauna Kea Management Board, University of Hawai'i, site users and other key stakeholders,
- Reporting to appropriate agencies,
- A plan to engage all site users potentially affected by the new invasive species,
- Dissemination of movement controls as they apply to risk items,
- A public awareness program.

MOVEMENT CONTROLS

The movement control plan should specify which items can or cannot be moved from the infested area(s) as well as prescribed approved treatment for disinfestations where this is possible. The costs of disinfestations and responsibility for meeting these costs also needs to be established.

BUDGET

Points to consider in the budget are, broadly speaking, expenses for human resources, transport, material and awareness measures or, in more detail:

- Human resources
 - salaries and wages,
 - overtime payments,
 - meal allowances,
 - costs of accommodation and per diems.
- Transport
 - hire of transport,
 - fuel,
 - spare parts, servicing and upkeep.
- Materials
 - Pesticides,

- inspection equipment,
 - treatment equipment,
 - first aid kit,
 - stationery.
- Public Awareness
 - radio or television announcements,
 - leaflets - design costs, number of leaflets.
- Restitution
 - Appropriate restitution for destruction of risk items and possible loss of access to infested sites.

RESEARCH PRIORITIES

The plan should address any gaps in knowledge that might impact on the success of surveillance or eradication. It is possible there may be unique issues that may need to be dealt with. Where knowledge gaps, or the need for more research or trial work exists, these should be identified in the plan.

Organizational Structure.

The control center should report to the ERMC, through the NRP Manager. The complexity of the organizational structure should be consistent with the size of the response. An organizational chart (Figure 5.3) shows the reporting relationships.

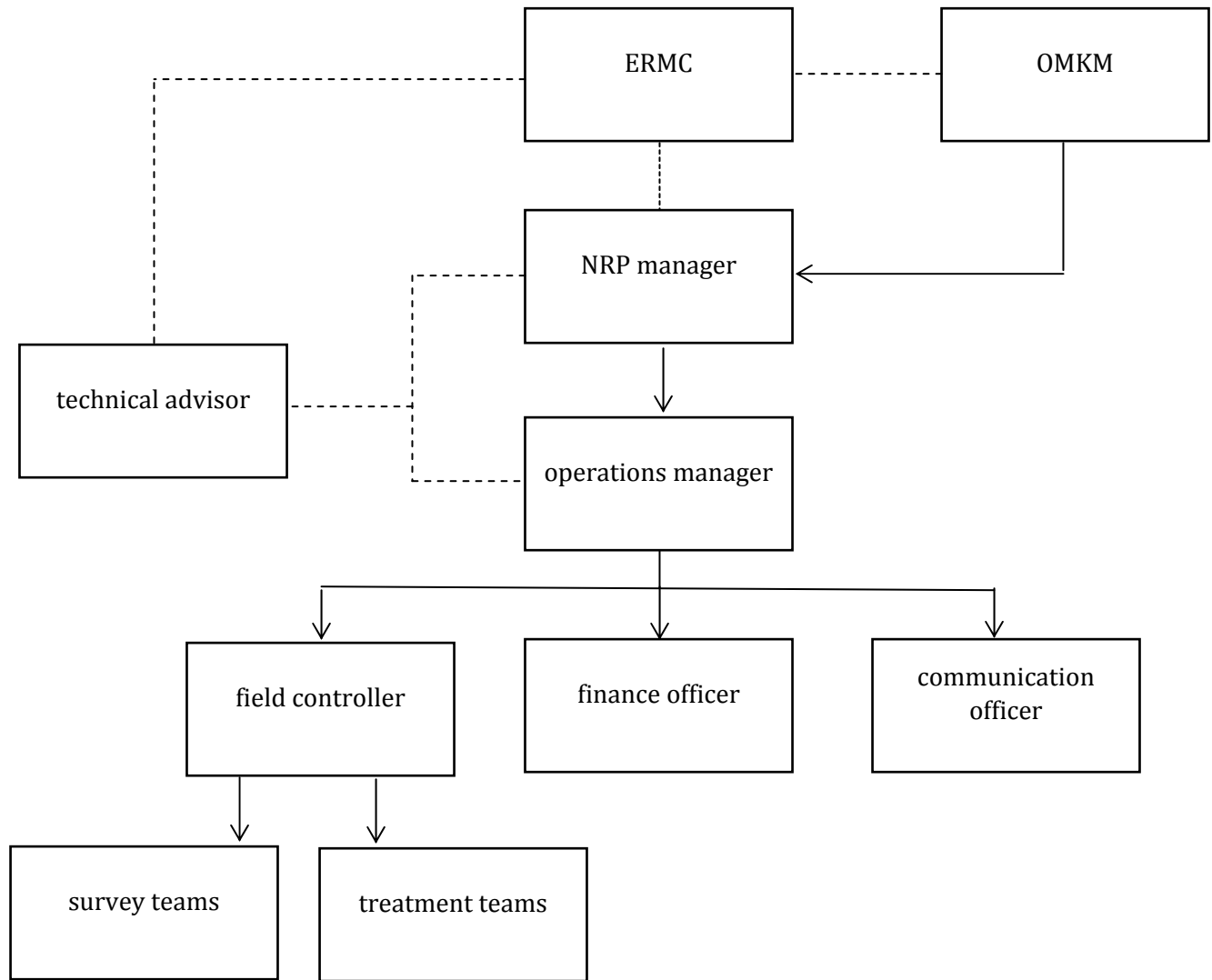


Figure 5.3. Organizational chart of the response team showing lines of authority (solid) and communication (dashed).

The duties and responsibilities of key staff are as follows:

THE NRP MANAGER

- provides monthly reports to the ERMC and answers queries.

OPERATIONS MANAGER

- Reports to the NRP manager,
- Is responsible for the overall implementation of the surveillance and eradication plans,
- Is responsible for the purchase of all the required equipment,

- Ensures that equipment is available when and where needed,
- Maintains an inventory of issued equipment,
- Organizes transport and accommodation,
- Selects and appoints a surveillance team and eradication team of qualified staff,
- Together with the Technical Adviser, briefs and trains the surveillance and eradication teams for their tasks. The trainers need to make sure that everybody knows their positions and understands their responsibilities,
- Supplies the surveillance team with:
 - surveillance plan and attachments,
 - surveillance equipment,
 - appropriate inspection and treatment documentation,
 - safety equipment and first aid kit,
 - datasheets, notebooks, pens, markers.
- Decides on improvements to the operation that are suggested by the Technical Adviser or Field Controller,
- Manages operational funds on a day-to-day basis,
- Reports expenses to the Finance Officer, and
- Requests new funds from the Finance Officer.

THE FIELD CONTROLLER

In a large response, this could become two positions: one managing surveillance and one managing treatment. For a smaller response, this position could be combined with that of the Operations Manager.

- Organizes surveillance and treatment schedules,
- Is responsible for day to day implementation of the operation,
- Ensures that:
 - appropriate procedures are followed,
 - infested products are disposed of or treated in the most appropriate way,
 - treatments are applied correctly.
- Decides on improvements to the operation suggested by the surveillance team, and
- Suggests improvements to the Operations Manager and Technical Adviser.

THE FINANCE OFFICER

In smaller operations, the finance officer may be a person working as an administrator in the lead department and have additional responsibilities not related to the response. In a larger operation, the Financial Controller will be a dedicated position.

- Reports to the Operations manager and ERMC,
- Is in charge of administration and finance,
- Establishes procedures that allow fast processing of payments,
- Ensures all appropriate governance requirements are followed, and
- Mobilizes new funds requested by the Operations Manager.

COMMUNICATION OFFICER

- Reports to the Operations Manager and ERM, C,
- Manages the flow of information,
- Prepares briefing notes to senior management, other political entities, and ensures appropriate persons are informed of developments. This includes communication with site users and the media,
- Prepares briefing notes and reports to ERM, C,
- Designs and implements public outreach strategy including contact with the media,
- Designs and implements outreach and engagement strategy to site users and other relevant stakeholders likely to visit or work within the areas being treated and surveyed, and
- Is the first point of contact for external agencies regarding progress and developments.

THE TECHNICAL ADVISER:

Briefs and trains the surveillance team and, in the case of an eradication, also the Field Controller, on their tasks and targets. The briefing is conducted together with the Operations Manager. The trainers need to make sure that everybody knows their positions and understands their responsibilities;

- Periodically monitors the operation to assess progress,
- Suggests improvements to the Operations Manager,
- Sources additional technical information for the ERM, C, and
- Suggests research priorities if required.

THE SURVEILLANCE AND TREATMENT TEAMS:

- Report to the Field Controller,
- Follow the procedures outlined in the surveillance and treatment plans,
- Treat and if necessary destroy host materials,
- Keep records of inspected, treated, destroyed or released risk items,
- Collect suspected samples and forwards them for identification, and
- Suggest improvements to the Field Controller and Technical Adviser.

Area Freedom/Pest Freedom

The accepted standard for declaring area freedom in an eradication is the absence of the invasive species for two lifecycles of the organism using accepted surveillance methods. For most insects, this period is two years, but for plants with long-lived seed banks, this period may be much longer. The frequency and extent of surveillance needs to be sufficiently rigorous to ensure the species is truly eradicated and new discoveries treated before they are able to reproduce and disperse.

The suggested frequency for post-eradication surveillance varies with the species in question. For insects, this should be a minimum of twice per year. For plants, the frequency should be at least twice within the period the species is known to grow from a propagule to reproductive stages. The

surveillance needs to cover all previously infested areas and the survey should be designed following methods accepted by the scientific community.

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Appendices

List of Standard Operating Procedures

Standard Operating Procedures (SOPs) will be updated per the adaptive management principles of this document. SOPs will take effect once approved by the Mauna Kea Management Board and (as required) by the DLNR Office of Coastal & Conservation Lands (OCCL); with the status field below updated to reflect the date of acceptance. This list of appendices is subject to change, the topics listed will all be addressed.

Plan Category	Standard Operating Procedure (SOP)	Content Notes	Status
Introductory Material (Intro)			
Intro	SOP-A	Reserved	
Intro	SOP-B Maunakea Vertebrate Threats, Identification, Collection, & Processing Guide	ID guide for vertebrates	not started
Intro	SOP-C Maunakea Invertebrate Threats, Identification, Collection, & Processing Guide	ID guide for arthropods, spiders	Submitted Jan. 2015
Intro	SOP-D Maunakea Plant Threats, Identification, Collection & Processing Guide	ID guide for plants	Internal review draft
Prevention (Prevent)			
Prevent	SOP01 Cleaning of Vehicles and Personal Belongings	Cleaning procedures	Submitted Jan. 2015
Prevent	SOP02 Inspection of Vehicles, Construction Materials, Scientific Equipment, & Supplies	Inspection procedures	Submitted Jan. 2015
Prevent	SOP03 Cafeteria Food Shipments (Receiving)	Cleaning & Inspection Procedures	Submitted Jan. 2015
Prevent	SOP04 Nursery Plant Treatment & Inspection	Adopt proven State methods	Adopt existing standard
Prevent	SOP05 Prophylactic Pesticide Use	Preventative site treatment	Not started
Early Detection (EarlyD)			
EarlyD	SOP10 Invasive Invertebrate Early Detection Surveys of Facilities	a) Locations b) Methods c) Analysis/Report	Submitted Jan. 2015
EarlyD	SOP11 Annual Alien Invertebrate Early Detection & Wēkiu Bug Monitoring	a) Locations b) Methods c) Analysis/Report	Internal review draft
EarlyD	SOP12 Maunakea Science Reserve Early Detection of Arthropod & Vegetation Surveys	a) Locations b) Methods c) Analysis/Report	Internal review draft
EarlyD	SOP13 Roads, Trails, & HP Early Detection of Arthropod & Vegetation Surveys	a) Locations b) Methods c) Analysis/Report	Not started

Rapid Response (RapidR)			
RapidR	SOP20 Arthropod Emergency Response	Rapid Response for Arthropods. (incl. Argentine Ant specific chapter as example)	Internal review draft
RapidR	SOP21 Emergency Response for Two Types of Woody Plants	Rapid Response for Woody plants	Not started
RapidR	SOP22 Emergency Response Plan for Two Types of Grasses	Rapid Response for grasses	Not started
RapidR	SOP23 Emergency Response Plan for Two Types of Herbaceous Plants	Rapid Response for herbaceous plants	Not started
Control (Control)			
Control	SOP30 Vertebrate Monitoring & Control, IACUC	Methods & IACUC approval	Not Started
Control	SOP31	reserved	
Control	SOP32 Control Plans for High-Priority Invertebrates Species	Priority Arthropod species control methods	Not started
Control	SOP 33 Control Plans for High-Priority Plant Species	Plants	Not started
Control	SOP34 Pesticide Use on Established Plant & Arthropod Species	Pesticide use for Plant & Arthropod control in designated areas	Not started
Control	SOP35 Control Plan for Halepōhaku, Road Corridor, Maunakea Science Reserve, & Astronomy Precinct	All taxa	Not started
Monitoring (Mon)			
Mon	SOP40 Plant Monitoring	Plant Monitoring. Maybe cross-reference with other SOPs	Not started
Mon	SOP41 Vertebrate Monitoring	Emphasis on 'uncontrolled' species such as birds. Other species monitored via 'control' SOP.	Not started
Mon	Invertebrate Monitoring	See SOP10 & SOP11	Cross-reference
Education / Outreach (Edu)			
Edu	SOP50	TBD	
	SOP51 Staff Training & Implementation	Staff training and procedures for inspection, species observations, etc.	In preparation
Other SOPs (Other)			
Other	SOP-Z Revising the Invasive Species Management Plan	Process to follow	Internal review draft
Other	SOP-Y TMT-Specific Instructions	Excerpts & Summaries	Updated as needed