HAWAI'I
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Forest Health 2012 highlights

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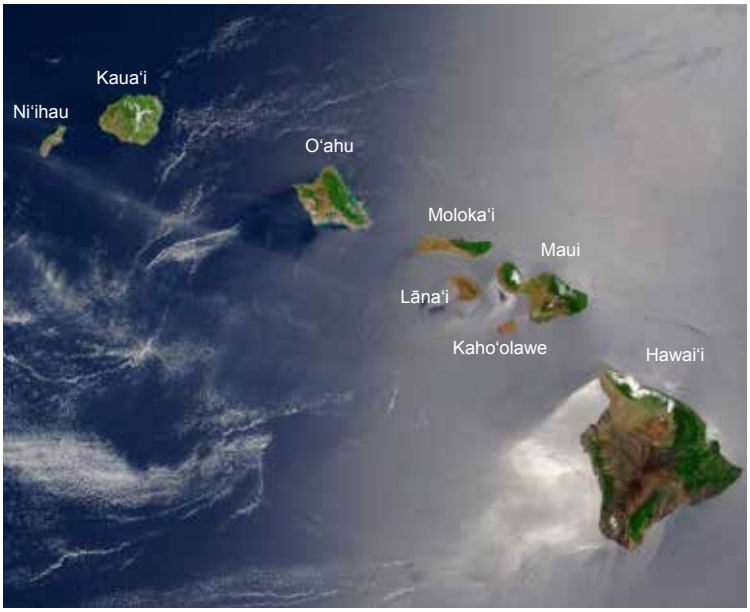
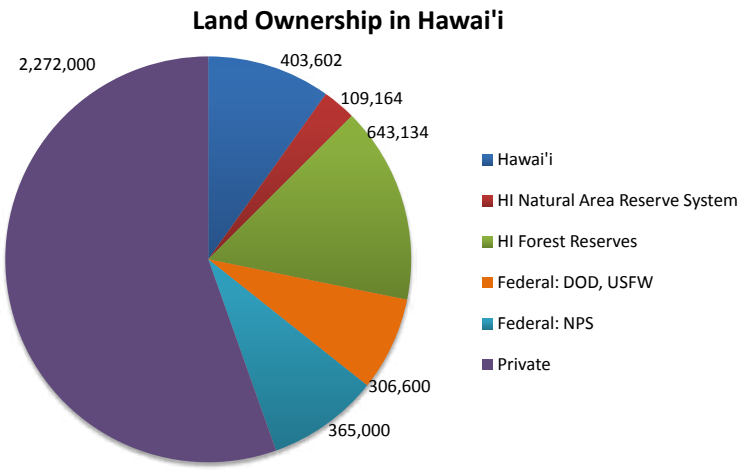
Forest Resource Summary

This report is for the State of Hawai'i which includes eight main islands (Kaua'i, O'ahu, Moloka'i, Lāna'i, Kaho'olawe, Maui, Hawai'i, and Ni'ihau) totaling 4.1 million acres. Public lands occur on all islands except Ni'ihau and Lāna'i, which are privately owned. Approximately 1.4 million acres of the state are considered forested. Non-forested areas include urban and agricultural areas, recent lava flows, and high elevation sites on Mauna Ke'a and Mauna Loa on Hawai'i and Haleakalā on Maui.

The State of Hawai'i Division of Forestry and Wildlife (DOFAW) manages 1,155,900 acres including 643,134 acres in forest reserves and 109,164 acres in the state's Natural Area Reserve System (NARS), which was created to preserve unique native Hawaiian ecosystems. Hawaii's state forest acreage ranks as the 11th largest in the nation. Federal lands account for 671,600 acres and are managed by the Department of Defense, National Park Service, and US Fish and Wildlife Service. The National Park Service is the largest federal landowner managing 365,000 acres. Although there are no National Forests in Hawai'i, the Hawai'i Experimental Tropical Forest was recently created on the island of Hawai'i as a partnership of USDA Forest Service and DOFAW. The HETF comprises over 51,000 acres and is co-managed by the Forest Service with DOFAW.





The remaining land – 2,272,000 acres – is privately owned. Increasing amounts of private forestlands are being managed in concert with publicly owned lands under public-private partnerships for watershed conservation in order sustain Hawaii's water supply. These watershed partnerships manage upland areas comprising a patchwork of federal, state, and private parcels. Eleven island-based Watershed Partnerships have been established on six islands to protect over 2.2 million acres (including non-forested lava flows and alpine areas). The partnerships actively manage approximately 300,000 acres of priority forest by removing invasive plants and animals.

Forest Health Monitoring in Hawai'i

Forest health monitoring occurs throughout the state on private, state, and federal lands. The spread and impact of invasive plants, invertebrate pests, diseases, biological control, and ungulates are monitored using ground surveys, transect monitoring, helicopter surveys, road surveys, photo points, and remote sensing techniques.

Monitoring forest health in Hawai'i presents many challenges

associated with its climate and geology. Hawaii's extremely rugged terrain limits ground access to many areas and increases the difficulty of remote monitoring due to vertical slopes and shadow effects. Watersheds can have as much as half of total land area in near-vertical slopes. The exceptionally rugged terrain creates extreme temperature and rainfall gradients that result in diverse ecosystems in close proximity. These transitions occur over a very small scale, so monitoring data collected over large scales is not typically representative of widespread conditions. Identifying species and classifying them as diseased or infested is a complex and difficult task. Additionally, a thick layer of clouds present much of the year often limits or prohibits remote sensing and aerial surveys of mountainous areas where much of Hawaii's forests are located.

Drought

Drought conditions continued through 2012 in Hawai‘i, with trends pointing toward a drier climate in the islands. Rainfall data collected by NOAA for 2012, as well as 30-year running averages, confirm this trend, potentially limiting forest extent. Recorded rainfall levels in 2012 fell 30-80% below average at various sites, and the leeward sides of Hawai‘i and Maui continue to experience extreme drought. Drought conditions are stressing forests, making them more vulnerable to pest infestations and leading to higher risk of wildfire. Forests in Hawai‘i are not fire-adapted and burns often result in the replacement of forest vegetation with fire-prone invasive grasses which perpetuates this destructive cycle. Drought conditions also limit restoration activities that rely on winter rains for seedling survival.

Disease Activity

‘Ōhi‘a Rust

Puccinia psidii

A rust disease on ‘ōhi‘a lehua (*Metrosideros polymorpha*) seedlings was first detected in a nursery on O‘ahu in 2005. The disease was eventually identified as *Puccinia psidii*, commonly known as “guava rust” in Florida and as “eucalyptus rust” in Brazil. It is considered to be a serious threat to several hosts in the Myrtaceae family in numerous tropical and subtropical countries. The disease is referred to locally as “’ōhi’a rust” because of the importance of this native tree, but it infects many species in Myrtaceae present in Hawai‘i. The disease is present on all major islands and can cause severe injury to ‘ōhi’a seedlings growing in nurseries.

Fortunately, only a single strain of *Puccinia psidii* is known to occur in Hawai‘i and this strain has not caused excessive injury to ‘ōhi’a trees which comprise about 80% of Hawaii's native forest. Monitoring of ‘ōhi’a and other myrtaceous species continued in 2012 to see which myrtaceous species *P. psidii* can infect and gauge its impact at different locations on each island. Five new hosts were documented in 2012 including *Syncaripia glomurifera*, *Pimienta racemosa*, *Eucalyptus resinifera*, and two *Sygyzium* spp. for a total of 33 documented hosts in Hawai‘i.

This year also marked the culmination of a five year intensive study to determine if there are other *P. psidii* strains in Brazil and their level of pathogenicty on ‘ōhi’a. Twenty-eight different strains were collected from various hosts across multiple locations. Five were tested for level of pathogenicty on ‘ōhi’a.

Three of the five *P. psidii* strains were highly virulent on most of the inoculated ‘ōhi’a seedlings, whereas the other two strains were much less virulent. None of the ‘ōhi’a families used in this test showed significant resistance to the three highly virulent strains of *P. psidii*. Infection by the highly virulent strains of *P. psidii* resulted, on average, in a 69% reduction in height growth and 27% increase in seedling mortality at 6 months post-infection. The conditions that these tests were conducted under were conducive for disease development; still, these results should have immediate implications for designing Hawaii's quarantine barriers. Results of the study will be published in Pacific Science and will support new quarantine restrictions at state and federal levels.

Rust symptoms found on a ‘ōhi’a seedling in a nursery.

Koa Disease Resistance

Koa (*Acacia koa*) is an endemic tree in Hawai'i that has special cultural, economic, and ecological importance. It is capable of fast growth and can produce wood character that makes it one of the most valuable woods in the world. It also provides habitat for much of the remaining native Hawaiian fauna and was used by Hawaiians for constructing voyaging canoes. For these reasons koa has been the focus for expanding the nascent timber industry in Hawai'i, as well as reforesting degraded lands.

Field planting of wilt resistant koa at HARC's Maunawili research station, Oahu.

There are several problems preventing koa from being more widely planted in Hawai'i, especially at lower elevations where it grows fastest. The vascular wilt fungus *Fusarium oxysporum* can cause mortality rates as high as 90% in some areas. In preliminary experimental plantings, foresters observed a marked variation in survival by family, suggesting genetic resistance.

Between 2006 and 2011, 500 koa seedlots were collected from the wild and tested for their resistance to pathogenic isolates of this fungus by the Hawai'i Agricultural Research Center (HARC). The range for resistance varied from 4 to 100%. In 2012 an additional 250 seedlots were collected and tested at HARC's Maunawili Field Station on the island of O'ahu. Resistant families are being outplanted into seed orchards to eventually provide landowners and managers with a source of disease-resistant planting stock.

Future activities include: continued screening of additional resistant koa families, retesting a subset of seedlots to examine repeatability of results, developing koa seed orchards capable of producing resistant seed, and refining methods for vegetative propagation of disease-resistant koa families.

Four-year old koa trees used for 2012 systemic insecticide trials at the Hawai'i Agriculture Research Center's Maunawili site.

In a related project, Forest Health Protection (Region 5) and Southern Research Station entomologists are working with HARC to evaluate efficacy of systemic insecticides for reducing insect predation of seeds which can be a limiting factor for producing disease-resistant seed. Twenty-nine trees from a seed orchard planted in 2008 were treated with the systemic insecticides Tree-äge (AI = emamectin benzoate) and IMA-jet (AI = imidacloprid) in March 2012 at HARC's Maunawili site using the Arborjet VIPER system. Sixty-eight trees from a seed orchard planted in 2007 were also treated in March 2012 at Hawai'i Reserves Incorporated's site in Laie. Leaf samples were collected at the Maunawili and Laie sites in April 2012 for residue analysis of emamectin benzoate and imidacloprid. Leaf and pod samples were also collected at both sites in August/September 2012 for residue analysis. Pods are also being examined for insect-caused injury.

Lac lobate scale infesting native Hawaiian hibiscus (*Hibiscus arnottianus*).

Insect Pests

Lac lobate scale

Paratachardina pseudolobata

The lac lobate scale was detected in 2012 on O'ahu in a botanical park not far from Honolulu International Airport. The scale was causing defoliation on a non-native ficus tree (*Ficus benjamina*). Surveys in the garden and surrounding area, including in a nearby forest reserve, detected the scale on several hosts including native hibiscus and koa (*Acacia koa*). In Florida and the Caribbean, the lac lobate scale has been documented on over 300 species including agricultural crops, forestry and landscaping trees, and native species. So far Hawai'i Department of Agriculture has documented the scale on 32 hosts, including 6 native plants. Systemic pesticides can be used to treat the scale in landscape and agricultural settings. Biocontrol efforts in Florida were stymied by mistaken identification of the pest and no agents are currently available. DOFAW is monitoring forest species for scale-caused injury to determine future management actions. So far the scale has only been reported on O'ahu.

Erythrina Gall Wasp

Quadrastichus erythrinae

The erythrina gall wasp (*Quadrastichus erythrinae* Kim) was first detected in 2005 when galls were observed on leaves and stems of ornamental Indian coral trees (*Erythrina variegata*) at the University of Hawai'i campus on O'ahu. Emergent adult wasps were identified as *Quadristichus erythrinae*, a species only previously described (2004) from specimens from Singapore, Mauritius and Reunion. The current distribution of the erythrina gall wasp (EGW) includes Taiwan, mainland China, India, American Samoa, Guam, Florida, and recently Puerto Rico. Adult wasps show a preference for ovipositing in young tissue, however when infestation levels are high, they are observed on leaves, petioles, young shoots, stems, flowers and seed pods. Generation time is rapid: the life cycle of the wasp (egg to adult) has been observed to be as short as 21 days in Hawai'i; the adult's life span varies from 3-10 days.

Once introduced, the tiny wasps were dispersed by wind and

Healthy blossoms on wiliwili (*Erythrina sandwicensis*).

the movement of people and goods to all Hawaiian islands where host species were present (Hawai'i, Kaho'olawe, Maui, Moloka'i, Lāna'i, O'ahu, Kaua'i, and Ni'ihau). Most *Erythrina variegata* trees were killed and removed. *Erythrina crista-galli*, also a common landscaping tree, is more resistant and trees continue to survive with minimal infestation, thus providing a year-round reservoir of erythrina gall wasp populations.

The native wiliwili tree (*Erythrina sandwicensis*) is the dominant tree species in most of Hawaii's dry forests. Although still considered abundant, little regeneration of wiliwili is occurring due to widespread seed predation by a bruchid beetle (*Specularis impressithorax*), competition from introduced grasses, fire, and severe browsing pressure on seedlings by introduced ungulates, in addition to the gall wasp. The impact of the gall wasp on natural wiliwili populations varied by stand; some populations remained relatively healthy while others were moderately to highly infested. Data collected in 2012 showed mortality rates to be as high as 40% in some stands.

A classical biological control program was pursued by the Hawai'i Department of Agriculture (HDOA) and the University of Hawai'i. Several potential agents were tested in containment facilities in Hawai'i as a result of multiple exploratory trips to Africa in 2005. After extensive host range testing, the first agent, *Eurytoma erythrinae* (Eurytomidae), was released in 2008 by HDOA at several wiliwili population sites throughout the state. The adult eurytomid wasp oviposits on galls; when its eggs hatch, the larvae consume the larvae of EGW. The biocontrol wasp spread quickly and has become established throughout

Galled seed pods on wiliwili (*Erythrina sandwicensis*).

Healthy wiliwili trees (*Erythrina sandwicensis*), displaying a diversity of flower coloration in Ulupalakua Ranch, Maui.

the state. Parasitism rates of EGW larvae inside galls range from 20-100% depending on location of the stand, time of year, and recent weather events. Galling levels on wiliwili trees have been reduced significantly and trees are recovering. In some areas managers are beginning to outplant wiliwili in restoration sites again.

Flowering, which had ceased in some stands at the height of the gall wasp infestation, has now resumed. However the infestation rate in flowers remains high, and consequently, seed production is adversely impacted. Monitoring is directed at assessing the impact of the released biocontrol agent on flowering and seed production. Preliminary data indicate that infestation by EGW severely effects floral development. Infestation rates vary dramatically depending upon the site, but rates of floral mortality have been observed to be as high as 40-100%. The impact on flower and seed production is not only an ecological concern, native Hawaiians have long used the beautiful red seeds of wiliwili for lei making, and the continued impact to this resource would represent a cultural loss as well.

Colonies of another natural enemy collected in Africa, *Aprostocetus nitens* (Hymenoptera: Eurytomidae), have been maintained at HDOA containment facilities in Honolulu. All necessary host range testing has been completed on this species, and initial competition trial testing indicates that the wasp does not adversely compete with the other eurytomid agent and its release would further control EGW populations. Given the continued impact to flower and seed production, resource managers believe release of a second agent may be necessary to stabilize wiliwili populations and ensure the survival of the species.

Myoporum Thrips

Klambothrips myopori

Myoporum thrips (*Klambothrips myopori*) is one of the most recent insect invaders in Hawai‘i. It was first detected in California in 2005, where it caused high levels of mortality in ornamental Myoporum species used for landscaping residential and freeway margins. In 2009 it was detected in Hawai‘i attacking the native tree *Myoporum sandwicensis*, locally known as naio. Its distribution in Hawai‘i is currently restricted to the island of Hawai‘i. The high mortality rates observed in California were of immediate concern to Hawai‘i, where naio is an appreciated native species. It is used often in ornamental plantings, holds cultural significance to native Hawaiians, and is an integral component of native Hawaiian ecosystems. While naio is most dominant in dry forests, and lowland and upland shrublands, it also populates mesic and wet forest habitats. Naio is distributed across all of the main Hawaiian Islands, and is present from sea-level to 3000m. The loss of this species would be a significant biological and structural loss to native forest habitats.

In September of 2010, the Department of Land and Natural Resources (DLNR) Division of Forestry and Wildlife (DOFAW) and the University of Hawai‘i with funding from the USDA Forest Service’s Forest Health Monitoring Program, initiated efforts to determine spatial distribution, infestation rates and overall tree health of naio populations on the big island. The specific project


0: No Galls


1: 1 - 33% Galled


1: 34 - 66% Galled


1: 66 - 100% Galled

Fig. 1 Infestation scale used in field monitoring of young tissue.


0: No Dieback


1: 1 - 33% Dieback


1: 34 - 66% Dieback


1: 66 - 100% Dieback

Fig. 2 Dieback scale used in field monitoring.

objectives are to: 1) define the current distribution of the naio thrips infestation on Hawai'i Island; 2) determine the impact of naio thrips across a variety of habitat types and elevational gradients; 3) monitor naio thrips density and distribution over time in infested areas, and measure rates of spread; 4) evaluate the potential for management and control of naio thrips; and 5) help train field personnel (state/federal/private) to detect naio thrips and identify incipient infestations.

Thrips feeding causes gall-like symptoms. Severe infestations can lead to branch die-back and ultimately to tree mortality. During monthly site visits, young shoots and branches are rated for infestation and dieback using a four point scale (Fig. 1 & 2). Data from two years of monitoring show that the infestation level in leaves increased considerably during the second year (2012), and that infestation levels are higher at medium elevation sites (Fig. 3). Similarly, dieback levels increased considerably during the second monitoring year, and were also higher at medium elevation sites (Fig. 4). Naio trees are experiencing tree mortality, which has also increased during the second year of monitoring.

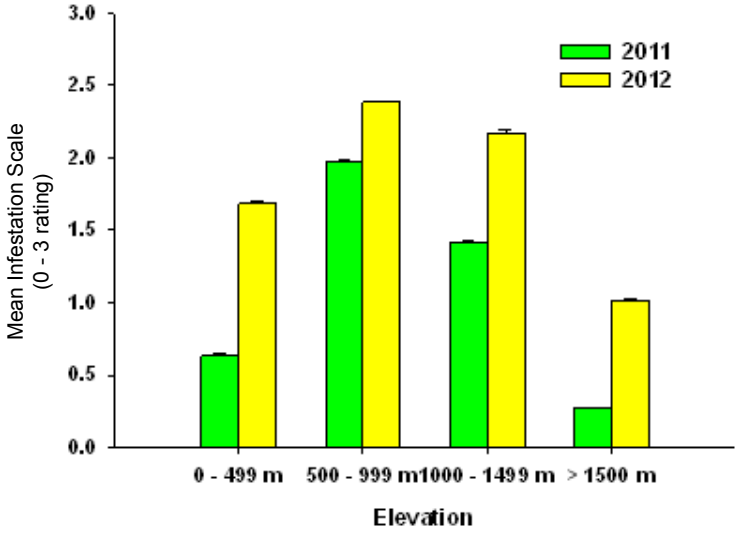


Fig. 3 Mean infestation level.

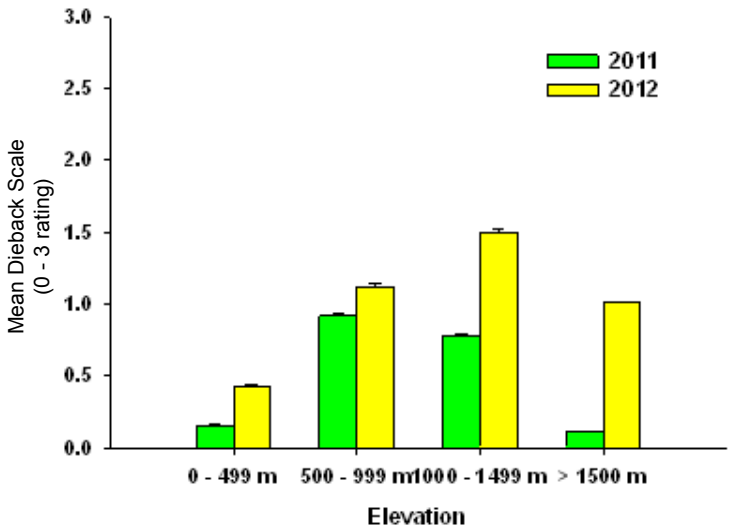


Fig. 4 Mean dieback level.

Invasive Plants

Poison Devil's Pepper Tree

Rauvolfia vomitoria

Poison devil's pepper, a tree native to Africa, was planted on agricultural lands in the North Kohala District of the island of Hawai'i and has infested nearly 10,000 acres of agriculture and forest lands. The tree is toxic and was planted for use as a medicinal/pharmaceutical plant and later abandoned. Its bright orange seeds are spread by many frugivorous exotic birds, and it threatens forested watershed in the vicinity where survey and control efforts are difficult due to steepness and dense vegetation.

Control efforts were initiated by the Big Island Invasive Species Committiee (BIISC) and the Kohala Watershed Partnership (KWP) who are working with the community to eradicate the species. This species is only known to occur in the state within this area (a mature tree at a botanical garden on the island of O'ahu was removed and surveys found no additional plants). Survey and control in forest areas is the first priority for controlling this species, with control of the core population in former agricultural lands requiring extensive resources to eradicate. In 2012 KWP successfully conducted surveys throughout forest areas bordering the core infestation and encountered fewer seedlings than predicted, thereby reducing the area of known infestation and providing time to develop tools for eventual eradication of the core population.

Poison devil's pepper is shallow-rooted and can be controlled manually in forest areas where densities are still low.

Poison devil's pepper fruiting.

Biological Control

Strawberry Guava

Psidium cattleianum

In 2012 Hawai'i Department of Agriculture and USDA Forest Service released the scale insect *Tectococcus ovatus* for the control of strawberry guava (*Psidium cattleianum*), one of Hawaii's worst forest weeds, at demonstration sites on the island of Hawai'i. The scale is being monitored by the Forest Service Institute of Pacific Islands Forestry. Establishment of the scale has occurred slowly but reproduction has been observed at the field sites. Outreach activities scheduled for 2013 will precede additional releases on Hawai'i and other islands where this invasive tree continues to invade and degrade native forests.

Galls caused by *T. ovatus* on strawberry guava.

Restoration

Mauna Kea Restoration Project

In 2002, two areas on Mauna Kea (approx. 6,500 acres total) were set aside to mitigate the impacts of road building through habitat of the native Palila, the last of the finch-billed honey-creeper species remaining in Hawai‘i. Historically these lands were covered with mamane (*Sophora chrysophylla*) forest and occupied by the endangered Palila, which relies almost entirely on mamane seeds as a food source. However, for many decades these areas had been managed for cattle ranching and grazed by feral sheep, and much of the forest was degraded with only remnant forest remaining.

The Mauna Kea Forest Restoration Project (MKFRP) was initiated in 2006 to restore mamane forests at these sites. Additionally, a fence was constructed around these areas in 2006 and both are now sheep-free. MKFRP is currently composed of seven staff. Management efforts include outplanting native seedlings and scattering seed; controlling invasive plants such as fountain grass, cape ivy and banana poka; controlling non-native predators that prey upon palila; fence inspections and maintenance; and running a thriving volunteer program that facilitates community involvement and ownership in the restoration process. MKFRP results include:

- 50,000 seedlings planted and 136 pounds of mamane seed scattered
- documentation of natural regeneration of mamane seedlings at 192 saplings/acre
- control of fountain grass populations
- removal of 159 feral cats from Palila Core Habitat
- maintenance of 48 miles of ungulate proof fence
- a volunteer program that has contributed 12,000 hours to MKFRP restoration efforts since 2010

Palila bird (*Loxioides bailleui*) on a mamane tree (*Sophora chrysophylla*).
Photo courtesy of David Leonard.

Control of invasive fountain grass (*Pennisetum setaceum*).

Data Sources

The data sources used for this report include the Division of Forestry and Wildlife, US Forest Service Region 5, Hawai‘i Department of Agriculture, University of Hawai‘i College of Tropical Agriculture and Human Resources, Hawai‘i Agriculture Research Center and other partner organizations.

Hawaii’s Watershed Partnerships, the National Park Service, The Nature Conservancy of Hawaii, and DOFAW’s Natural Area Partnership System also conduct monitoring of invasive plants and ungulates to improve the effectiveness of their management activities, but those data are not the focus of this report. The USDA Forest Service’s Forest Health Forest Inventory and Analysis Program was recently introduced to Hawai‘i , but results from the survey are not yet available.

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USDA United States Department of Agriculture