Contents

Forest Health highlights

○ HAWAII

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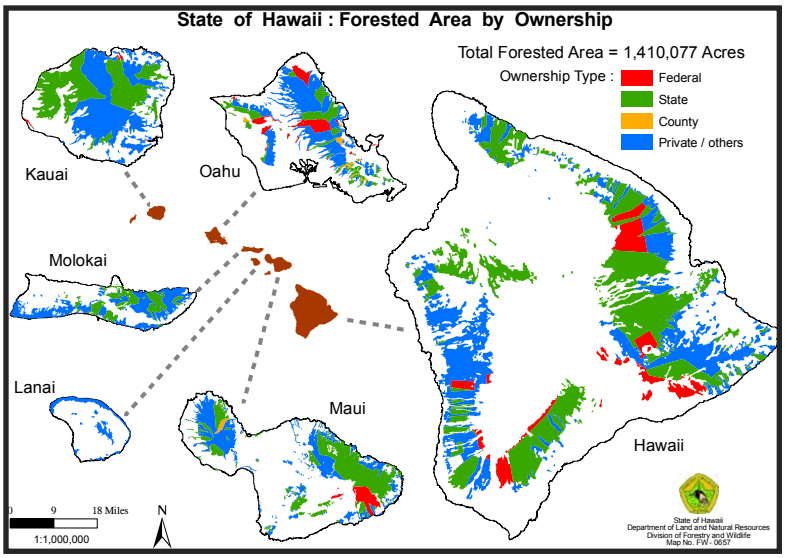
Forest Resource Summary

This report is for the State of Hawaii which includes eight main islands (Kauai, Oahu, Molokai, Lanai, Kahoolawe, Maui, Hawaii, and Niihau) totaling 4.1 million acres. Public lands occur on all islands except Niihau and Lanai, which are privately owned. Approximately 1.4 million acres of the state are considered forested. Non-forested lands include urban and agricultural areas, recent lava flows, and high elevation sites on Mauna Kea and Mauna Loa on the island of Hawaii and Haleakala on the island of Maui.

The State of Hawaii 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), making Hawaii's state forest the 11th largest in the nation. The NARS was created to preserve unique native Hawaiian ecosystems and is also managed by the Division of Forestry and Wildlife. 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. There are no lands in Hawaii managed by the US Forest Service.



The remaining land – 2,272,000 acres – is privately owned. Increasing amounts of private forestlands in mountainous areas are being managed for watershed conservation in concert with publicly owned lands under established partnerships. These watershed partnerships manage upland areas comprising a patchwork of federal, state, and private parcels. They currently manage a combined total of 850,000 acres throughout the state.

Forest Health Monitoring in Hawaii

Monitoring of forest health conditions occurs throughout the state on private, state, and federal lands. The program objectives include monitoring the spread and impact of invasive plants, invertebrate pests, diseases, biological control agents, and ungulates. Ground surveys, transect monitoring, helicopter surveys, road surveys, photo points, and remote sensing are used for data gathering.

Monitoring forest health in Hawaii 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 making monitoring data collected over extensive areas very difficult to interpret. Identifying species as well as 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.

Ohia Rust
Puccinia psidii
A new rust disease on ohia (*Meterosideros polymorpha*) seedlings was detected in a nursery on Oahu in April 2005. The same disease was later found on rose apple (*Syzygium jambos*) growing in forests on Oahu. The disease was eventually identified through DNA analysis as *Puccinia psidii*, commonly known as "guava rust" in Florida and as "eucalyptus rust" in Brazil. The disease is referred to locally as "ohia rust" because of the importance of this native tree, but it infects many species in the Myrtaceae family that are present in Hawaii, in addition to ohia. The disease is present on all major islands and is likely to have spread between islands by wind and the movement of infested ornamental plants.

Confirmed host species of *Puccinia psidii* in Hawaii.

Scientific Name	Common Name
Chamelaucium uncinatum	waxflower
Eugenia koolauensis (H)	Nioi
Eugenia paniculatum	Brush cherry
Eugenia reinwardtiana (H)	Nioi/Beach cherry
Eugenia uniflora	Surinam cherry
Melaleuca quinqeunervia	Paper bark
Meterosideros excelsa	Pohutukawa
Meterosideros kermadecensis	Kermadec pohutukawa
Meterosideros polymorpha (H)	Ohia
Meterosideros tremuloides (H)	Ohia
Myrciaria cauliflora	Jaboticaba
Myrtus communis	True myrtle
Psidium guajava	Common guava
Rhodomyrtus tomentosa	Downy rosemyrtle
Syzygium cumini	Java plum
Syzygium jambos	Rose apple
*Syzygium malaccense**	Mountain apple
Syzygium paniculatum	Australian brush cherry

(H) Native to Hawaii
* Artificially inoculated in laboratory


Ohia seedling (*Metrosideros polymorpha*) infested by *Puccinia psidii* in an Oahu nursery.

Defoliation of rose apple (*Sygyzium jambos*) by *Puccinia psidii* on Maui.

The disease has been reported on eighteen different species in the environment, four of which are native to Hawaii including one endangered species. An additional six species including several *Eucalyptus spp*. have been artificially inoculated using inoculum isolated from rose apple. However eucalypts have not been found infected in the environment.

The disease infects young leaf tissue producing bright yellow pustules and causes stunting and shoot dieback on the plant. In some species it also infects reproductive material. The rust rarely kills its host however. Bright yellow-orange pustules develop on plant tissue until the tissue dies. Susceptibility of hosts varies widely among species. In Hawaii the non-native rose apple displays the most dramatic symptoms with observations of all new shoots within in a stand being killed by the disease. Infections on ohia have been reported mostly in nurseries where either environmental conditions or abundance of young, susceptible foliage appears to be conducive to outbreaks of the rust. Some ohia varieties do not develop symptoms when growing in infested nurseries. Detections of the disease in native forests have been at very low levels, and it does not appear to be strongly impacting ohia forests at this point.

The disease is a serious threat to Hawaii's native forest. Ohia is the dominant tree species in much of Hawaii's remaining native forests and provides important habitat for endangered birds. Adaptation and increased virulence of the rust disease on ohia is considered a likely development. Commercial eucalyptus

plantations could also be threatened, especially as plantations are harvested and replanted. *Eucalyptus* seedlings of commercial species such as *E. grandis* are very susceptible to injury from *P. psidii* in Brazil, although susceptibility in laboratories in Hawaii to local inoculum was found to be minimal on *E. grandis*.

A Special Detection Survey funded by Forest Health Monitoring is underway. The survey is being carried out by University of Hawaii and they are attempting to document the host range, as well as the environmental conditions that are required by the disease to infest its hosts. So far disease presence has been confirmed on all major islands and at elevations as high as 4,000 feet.

Based on preliminary DNA analysis by University of Hawaii and Forest Service, the disease strain in Hawaii is different from strains in Florida and Brazil. A study is underway to determine genotypes of the disease in Hawaii as well as in Brazil and the mainland US. Different strains have different host-ranges and can vary in virulence. The Hawaii State Department of Agriculture established an interim quarantine rule in August 2007 to prohibit host material (all species of Myrtaceae) from entering the state from areas known to have *Puccinia psidii*.

Scientists collect spores of *Puccinia psidii* for DNA analysis.

Koa Wilt
Fusarium oxysporum f.sp. koae

Koa wilt disease was first described in 1980 on the island of Hawaii and was attributed to the pathogen *Fusarium oxysporum* f.sp. koae. The pathogen infects trees through their roots and causes injury to the vascular system, sometimes leading to crown dieback and tree death. It is not known where the disease originated or how the disease spreads in the environment. Other areas of koa dieback were reported throughout the state thereafter, but little work had been carried out on the disease until the last few years, despite the ecological, cultural, and economic importance of koa to the state of Hawaii.

Although wide-scale dieback has not been observed in forests, there has been a high incidence of the disease causing high mortality rates in koa plantations, especially on former agricultural lands. A survey for koa wilt was conducted in 2004-2005 by the Hawaii Agriculture Research Center and DOFAW with funding from USDA Forest Service Forest Health Protection. Surveyors located areas with symptomatic trees and collected root, stem, leaf, and seed samples for isolating *F. oxysporum* in the laboratory. Diseased trees were sampled in both plantations and natural forests throughout the state.

Dead or dying trees testing positive for *F. oxysporum* were found on all of the major islands where koa commonly grows. Trees in both planted and natural forests were found infected with the pathogen that is attributed to causing koa wilt disease. *F. oxysporum* was found most commonly on roots and soil near diseased trees. Interestingly, other *Fusarium* species were also isolated from sampled tissue, and pathologists are exploring the role of these other species in the disease etiology. Methods of sampling for the disease were refined in this survey facilitating future survey and monitoring for the disease. Outreach materials on koa wilt were developed by the University of Hawaii and can be found at: http://www.ctahr.hawaii.edu/forestry/index.asp.

Many questions remain unanswered regarding koa wilt. The extent of the disease in natural forests is not known, nor is whether the pathogen exists in healthy forests. Knowing how the disease spreads in the environment is also crucial for management. In a 2007 survey of nurseries that provide planting stock to conservation areas, *F. oxysporum* along with other *Fusarium spp*. was found to be prevalent on koa seedlings.

What appears to be genetic resistance has been observed in koa plantations trials, and efforts to develop genetic resistance for plantations are being pursued. Koa families from each island are being screened for resistance by inoculating seedlings with pathogenic strains of *F. oxysporum*. Resistant families will be planted in seed orchards on respective islands to provide seed for plantings.

Koa seedlings inoculated with pathogenic strains of *Fusarium oxysporum* at the Hawaii Agriculture Research Center's station on Oahu. Seedling trials provide information on disease resistance of different koa families.

Erythrina Gall Wasp
Quadrastichus erythrinae
The Erythrina gall wasp (*Quadrastichus erythrinae* Kim) continues to infest native and non-native *Erythrina* spp. Galls caused by EGW were first detected in April of 2005, on ornamental Indian coral trees (*Erythrina variegata*) at the University of Hawaii campus on Oahu. Emergent adult wasps were then positively identified as *Quadristichus erythrinae* Kim, a species only recently described (2004) from specimens from Singapore, Mauritius and Reunion. The current distribution of the Erythrina gall wasp also includes Taiwan, mainland China, India, American Samoa, Guam, Saipan, Tinian and most recently Florida. Adult wasps show a preference for ovipositing in young tissue and galls have been observed on leaves, petioles, young shoots, stems, flowers and seed pods. Generation time is rapid: the life cycle of the wasp (egg to adult) can be as short as 21 days in Hawaii; the adult's life span varies from 3-10 days.

Once introduced, the tiny wasps were easily dispersed by wind and the movement of people and goods and spread rapidly to all neighboring islands where host species are present (Hawaii, Kahoolawe, Maui, Molokai, Lanai, Oahu, Kauai, and Niihau). Most *Erythrina variegata* trees have been killed and removed. *Erythrina crista-galli*, also a common landscaping tree, is more resistant and trees continue to survive with minimal infestation.

The native wiliwili (*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 the bruchid beetle (*Specularis impressithorax*), competition from introduced grasses, and severe browsing pressure by introduced ungulates, in addition to the recent outbreak of Erythrina gall wasp. The impact of the gall wasp on natural wiliwili populations is variable, with some populations still healthy while others are moderately to highly infested. Wide scale mortality of native coral trees has not yet occurred. Seed production was low or non-existent in many native populations in 2006; however, in 2007 seed production increased reported at several sites.

A wiliwili tree (*Erythrina sandwicensis*) on Kauai with light gall wasp infestation. Photo: Rob Hauff

Quantifying Erythrina gall wasp pressure with sticky traps in a native wiliwili forest on Maui. Photo: Rob Hauff

Experimental trials using systemic insecticides such as imidicloprid have had mixed results. Soil drenches are difficult to apply effectively for uptake by the tree's root system and impractical in a forest setting. Several injection systems have been tested with some success but are costly, and infested trees must have leaves in their canopy for the chemical to be translocated. Foliar treatments have been effective but are expensive and less practical.

The Hawaii Department of Agriculture and the University of Hawaii have made exploratory trips to Africa for biological control agents. A parasitoid wasp in the family Eurytomidae is currently undergoing approval for release and will likely be released in 2008. Two other parasitoids of *Quadrastichus spp*. found in Africa are currently being studied in quarantine facilities in Honolulu.

Black Twig Borer
Xylosandrus compactus
The black twig borer was first detected in Hawaii in 1931 and has an extremely wide host range. In Hawaii, at least 108 tree and shrub species belonging to 44 plant families are attacked by the black twig borer. Several federally listed threatened and endangered species are impacted by black twig borers and its associated fungus *Fusarium solani*, including *Flueggea neowawraea*, *Alectryon macroccoccus*, *Melicope saint-johnii*, *Gardenia mannii*, and *Caesalpinia kavaiensis*. The borer also commonly attacks koa, and koa seedlings can suffer high mortality rates in nurseries and outplantings due to the physical disruption of seedlings' vascular system caused by bore holes.

Plant injury caused by the black twig borer damage is usually worse during drought years but affects plants during wet years as well. The borer is ubiquitous in forested areas under 2500 feet elevation and host species are abundant in all forest types. Monitoring therefore, is not a high priority, except for injury to rare and endangered species. Experimentation with trapping using chemical attractants around vulnerable species continues.

Invasive Species Committees

Hawaii's island-level Invasive Species Committees (ISCs) became active in the 1990s with the goal of being able to respond to threats of alien pest infestations and to control established pest populations on a species by species basis. The Maui Invasive Species Committee (MISC), the Molokai subcommittee of MISC (MoMISC), the Big Island Invasive Species Committee (BIISC), the Kauai Invasive Species Committee (KISC), and the Oahu Invasive Species Committee (OISC) are already well involved in the battle against invasive species. Each ISC is a voluntary partnership of county, state, and federal agencies, private businesses, nonprofit organizations, and individuals united in cooperative efforts to control the alien pest species that pose the greatest threats to each island's ecosystems, watersheds, economy, public health, and quality of life.

Hawaii is unique in our extreme isolation from other terrestrial biodiversity centers. Once an invasive species becomes established in the state, individual islands may remain free of pest species through intra-state quarantine practices and constant monitoring, followed by effective control and island-wide eradication. Island-wide eradication is the most cost-effective, long-term protection for native ecosystems. While several of the highest priority plant species are fairly widespread based on surveys, new targets will be prioritized by the level of the threat they pose to native ecosystems and the feasibility of eradication. This strategy will lead to the most cost-effective, long-term protection for Hawaii's forests.

The ISCs work to prevent incipient species from becoming established in Hawaii's watersheds and natural areas. While the ISCs' geographic scope is island-wide, much of their work is focused in the lower elevation areas, at or near the boundaries of the Watershed Partnerships, on residential or rural properties, or on disturbed forest lands where incipient populations of invasive species are found. When the ISCs work in forested mountain areas, they often collaborate with the Watershed Partnerships. ISCs may also work on targeted agricultural pests. ISCs typically do not work on controlling species such as pigs or goats which are both widespread and not good candidates for species-based management.

Early Detection

Early detection is the best prevention against invasive species. It emphasizes building and refining a target list, performing targeted surveys, and prioritizing species for control based on distribution and risk. The goal is to find an invasive species before it spreads.

Invasive Species Committees have implemented early detection and rapid response programs to achieve island-wide eradications. ISC crews survey roads, nurseries and other pathways of introduction to protect the islands from weeds while they are still easy to control. This species-led approach is much more proactive than waiting until introduced species are wide spread and causing negative impacts on forests.

When a new plant species is detected, the Weed Risk Assessment (http://www.botany.hawaii.edu/faculty/daehler/wra/) is used to predict the plant's potential to become weedy. The WRA was developed in Australia and New Zealand and modified for use in Hawai'i and other Pacific islands by Professor Curt Daehler of the University of Hawai'i. The WRA screens plant species and assigns them a score based on their propensity to become weedy. Plants that have a high level of threat to the island and a low level of establishment represent the highest priority for control and become targets for rapid response. Once a species becomes a rapid response target, crews begin to systematically survey and control all known populations to eradicate it from the island.

For example, on Oahu botanists are surveying areas with high potential for new introduced plants that may be invasive. These "hotspots" encompass myriad sites that were categorized and prioritized to provide the best sampling possible. The hotspots include areas such as experimental agriculture sites, botanical gardens and nurseries. From over 22 hotspot surveys, the Oahu team identified and documented over 1,200 species. Of these, 175 were not already catalogued at the Bishop Museum's Herbarium Pacificum, meaning they are possibly very recent arrivals to Oahu. Seventeen of these 175 species have been documented as weeds elsewhere in the world and may become targets for OISC eradication. Hightlights of the survey include 133 high-risk species, 12 new naturalized weed records for the state and 13 others for Oahu. Currently botanists are conducting roadside surveys for these weeds throughout the island. Similar projects are underway on the other islands.

The Oahu Invasive Species Committee had two successes in early detection/rapid response during 2007. Three populations of kudzu (*Pueraria montana var. lobata*) were detected by OISC crews and controlled. Crews continue to do follow-up control at the three sites. Purple-headed vervain (*Verbena bonariensis*), a weed previously not known to occur in Hawaii, was detected in a roadside area treated with hydromulch. Workers removed all plants from the 11 acre infestation and follow-up control continues.

Priority Target Species

All of the species targeted by the ISCs are able to outcompete or drastically alter existing communities, resulting in a change in ecosystem components, structure and function. Some plants, like fountain grass and bushy beardgrass, also change the fire regime of an area. Animal species like coqui consume large amounts of insects, and veiled chameleons are able to take birds, disrupting pollination services and further jeopardizing threatened and endangered species. Some species also impact ecosystems and human health and quality of life, such as long-thorn kiawe, little fire ants and coqui frogs. The following is a description of several ISC target species, but it is not a comprehensive list of ISC targets.

Visit: http://www.hear.org/
for a comprehensive list of ISC targets

Miconia

Miconia calvescens

Miconia is the highest priority statewide for invasive weed control and was originally introduced to Hawaii as an ornamental plant. Miconia can displace native flora, negatively impact the water supply, result in a loss of species diversity and cause permanent changes to ecosystem function, such as alteration of primary productivity and nutrient cycling. Miconia completely replaces native vegetation resulting in total loss of native habitats.

Miconia is present at varying levels on Hawaii, Maui, Oahu, and Kauai (listed in order of most severe to least). On Hawaii, it is not possible to eradicate the species with the tools and resources available, while on Kauai no mature trees have been found since 2004. Maui and Oahu fall between. Early detection aerial surveys have yet to detect miconia on Molokai, but introduction there is a serious concern.

Because the level of infestation differs on each island, management goals and strategies vary among ISCs. Each ISC uses helicopter surveys and ground surveys to locate trees, saplings and seedlings. Helicopter surveys are essential in Hawaii because of the extremely rugged terrain, and they have proved very effective at detecting mature miconia trees. Ground surveys conducted by invasive species technicians and volunteers locate and eliminate miconia plants in accessible areas using a 800 meter buffer around mature trees. The USDA Forest Service Institute of Pacific Islands Forestry and Hawaii Department of Agriculture are conducting host specificity studies on insects and pathogens to release for biological control of miconia.

Miconia calvescens - Miconia (Melastomataceae)
Leaf at Hilo, Hawaii.
Photo by Forest & Kim Starr
Available at: www.hear.org

Data Management

During 2007, staff from the U.S. Geological Survey's Pacific Basin Information Node completed work with the Invasive Species Committees to unify portions of each ISC's data management system. The result of this process was the establishment of a reliable and efficient statewide reporting system on invasive species that allows us to generate reports as required by funding agencies. The new, integrated reporting system will continue to be improved to provide current information about efficacy and status of control efforts.

Site-led Management

In contrast to the ISCs' "species-led" management, many entities in the state carry out "site-led" management of established invasive species to protect high-value conservation areas. Examples include Hawaii's Watershed Partnerships, the National Park Service, The Nature Conservancy of Hawaii, the Department of Defense, and the Natural Area Reserve System. Target species include established ungulates and invasive plants such as strawberry guava, clidemia, Kahili ginger, and tibouchina. Targets are monitored and controlled using manual, chemical, and sometimes biological control.

Many of these established invasive plants will only be managed effectively in the long-term with the use of biological control. USDA Forest Service and Hawaii Department of Agriculture carry out biological control research essential to weed management in the state. A new biological control agent for strawberry guava, a gall-forming scale, is likely to be released in 2008 by Forest Service researchers on the island of Hawaii (this work has been supported by FHTET and the STDP program). The insect offers hope for reducing the impact of this destructive weed, as well as reducing the amount of resources necessary for controlling it with herbicides in protected areas. The release sites will be monitored for at least two years before releases are made on other islands.

Feral Ungulates

Feral ungulates are extremely damaging to Hawaii's forest ecosystems. Pigs, cattle, deer, goats, and sheep all damage forests throughout the state by eating and trampling vegetation and causing erosion. They also contribute to the spread of invasive plants by dispersing seeds of aggressive weeds such as guava and by disturbing the forest floor and soil allowing some of the worst invasives such as clidemia to establish. Pigs are widespread on all major islands, but presence of the other animals varies from island to island. While public hunting suppresses animal populations in some areas, many of the more remote areas where native forests are located do not benefit from public hunting. Management activities focus on fencing to keep ungulates out of priority areas and reducing animal populations using public and staff hunters, traps, aerial shooting, and occasionally snares.

Feral pig in Hawaii Volcanoes National Park. Photo by Jack Jeffrey

Monitoring ungulate populations in Hawaii is very difficult, and no accurate population estimates currently exist for any of the taxa mentioned above. Wildlife managers sometimes survey hunting areas to assess population levels before hunting seasons begin, and hunters are required to report kills at designated hunting stations. In 2006 public and staff hunters reported 5076 feral animals killed on state lands including 1455 pigs and 1417 goats. Other damaging ungulates killed include mouflon sheep, axis deer, black-tailed deer, and feral sheep.

Pig monitoring in conservation areas typically involves recording signs of animal presence along five meter wide transects. This type of monitoring occurs throughout the state primarily in native forests. These data can be used to direct hunting efforts or to strategically locate fences. Feral cattle in forest reserves on the island of Hawaii are monitored using helicopters. Cattle detected from the air are recorded with GPS and later hunted. Similarly pigs and the damage they cause are monitored during helicopter surveys in areas such as the Alakai Wilderness Area on Kauai.

Data Sources

The data sources used for this report include data gathered by Hawaii's island-based Invasive Species Committees or ISCs (funded in part by Forest Service FHP Prevention and Suppression Program), Division of Forestry and Wildlife staff, Hawaii Department of Agriculture, University of Hawaii, and partner organizations such as the Hawaii Agriculture Research Center. Survey and monitoring data collected by the ISCs are entered into a statewide database created by the Hawaii Natural Heritage Program, and the data are analyzed at the local and state levels.

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 Aerial Survey Program and Forest Inventory and Analysis Program are not currently active in Hawaii.

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