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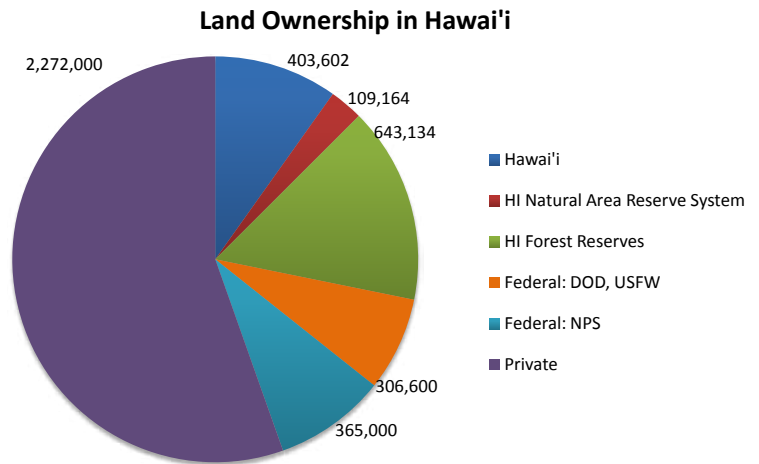
Forest Health *2013 highlights*

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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

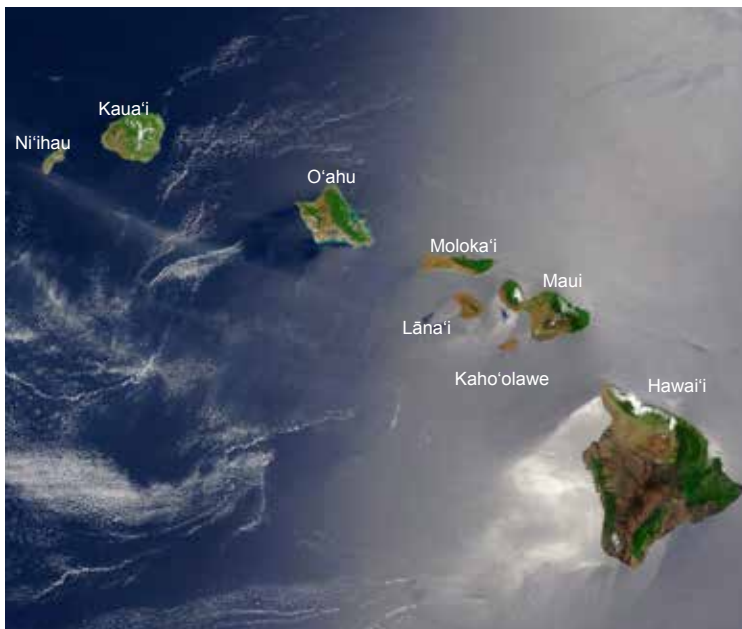


was recently created on the island of Hawai'i as a partnership of USDA Forest Service and DOFAW. The HETF comprises over 51,000 acres and is co-managed by the Forest Service with DOFAW.

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 most of 2013 in Hawai'i, with trends pointing toward a drier climate in the islands. Rainfall data collected by NOAA for 2013, as well as 30-year running averages, confirm this trend, potentially limiting forest extent. Leeward Haleakala on Maui and North Kohala District of Hawaii Island were particularly dry in 2013. Rains arriving in the 2013-2014 wet season alleviated drought in some areas but missed many of the worst drought areas. 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.

'Ōhi'a (Myrtaceae rust and Puna die-off)

'Ōhi'a (*Metrosideros polymorpha*) is the most common tree species in Hawai'i's native forests, growing from sea-level to nearly 8000 feet and in dry, mesic, and wet forests. This abundant tree provides habitat to much of the native flora and fauna and also has significant cultural importance. The name 'ōhi'a means 'to gather' in the Hawaiian language, referring to the tree's ability to collect water from the rain and mist, feeding the aquifers that sustain life on this remote archipelago.

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.

Multiple strains of *Puccinia psidii* have been found to be associated with different hosts in Brazil (Graca et al., 2011). 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. A study conducted in Brazil found 'ōhi'a families to be more susceptible to several of the stains isolated in Brazil (da Silva et al., 2014). This information is being used by quarantine officials at state and federal levels to protect Hawaii from accidental introduction of additional, more harmful strains of the disease.

Monitoring of forests for *P. psidii* continued in 2013 to determine which species are susceptible and gauge its impact to 'ōhi'a at different locations on each island. During surveys, rust was documented on coppice growth of *Eucalyptus grandis* plantations on Hawaii Island that had recently been harvested. Recently planted 'ōhi'a seedlings at a restoration site were also heavily infested by *P. psidii* likely due to lack of hardening off before outplanting. No damage to mature 'ōhi'a trees in the forest was documented however.

During rust surveys, a die-off of 'ōhi'a determined to be unrelated to the rust disease was detected in the Puna District on the Big Island. Follow-up surveys delineated the area affected totaling approximately 1000 acres. The pattern of tree death is distinguishable from "classical ohia dieback," studied extensively in the 1980's and determined to be a type of cohort senescence. Trees in this case are observed to die rapidly, with dead, brown leaves intact. Residents in the area are reporting trees dying on their property at an alarming rate. Cause of the die off is being investigated. The die off is occurring primarily on the older lava flows in the area.



Aerial photos of a healthy Ohia forest stand in 2008 (above) and the same Ohia stand in 2012 (below) following sudden Ohia death. Mature Ohia trees in photo are 20 to 25 m in height. (F. Hughes)

Koa (koa wilt disease, seed predators, endemic koa moth outbreak)

Koa (*Acacia koa*) is an endemic tree in Hawai'i that has special cultural, economic, and ecological importance. Second in abundance only to 'ōhi'a, it makes up much of the watershed forests, frequently growing beside 'ōhi'a in mixed forests. 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.

Disease

There are several problems preventing koa from being more widely planted in Hawai'i, especially at lower elevations where it grows fastest. One of the biggest challenges is the vascular wilt fungus *Fusarium oxysporum* f.sp. *koaea* (FOXY) which 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.

The Hawai'i Agriculture Research Center (HARC), in collaboration with the Division of Forestry and Wildlife and private landowners, is developing disease resistant koa for commercial plantations as well as forest restoration. In 2013, 130 new koa seedlots were collected from the wild and tested for their resistance to pathogenic isolates of FOXY resulting in 33 new resistant families. Resistant families are being planted into seed orchards on each island in state forest reserves to test durability of resistance and provide managers a source of disease-resistant planting stock.

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

Insect Agents

Seed Predators: In addition to disease resistance, 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 in orchards, and to determine longevity of systemic insecticide treatments. 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 Hawaii Reserves Incorporated's Laie site. In 2013 seed pods were collected from 30 study trees at the Maunawili orchard in August, and at the Laie orchard in September, for bioassay. Data recorded for each pod included total number seeds, number of undamaged seeds, number of seeds damaged and by what insect, number with unknown damage and number of aborted seeds. These data are being analyzed to determine treatment efficacy.

Black Twig Borer (*Xylosandrus compactus*): An addition study was initiated in 2013 by FHP and HARC to evaluate efficacy of systemic insecticides to reduce black twig borer predation of disease resistant *Acacia koa* seedlings. The black twig borer (BTB) is an invasive ambrosia beetle first reported in Hawaii in the mid-20th century. It has since spread throughout the state and is a major forestry, ornamental and agricultural pest, with over 150 known hosts in Hawaii. The BTB which farms *Fusarium solani*, a non-pathogenic fungus, damages koa and other host field plantings following establishment, thus hindering restoration and reforestation efforts.

Approximately 220 koa seedlings were selected for the study and transplanted into large growing containers to allow for growth during the duration of the trial. In July 2013, 192



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



Koa seedlings treated to evaluate efficacy of systemic insecticides to reduce black twig borer predation, 2013.



Stem breakage of koa caused by infestation by black twig borer.

healthy seedlings were selected and separated into six groups; 32 for each treatment and the control. Seedlings were treated with one of four systemic insecticides: imidacloprid, fipronil, dinotefuran or spirotetramat. In addition, in September 2013, 32 previously untreated seedlings were treated topically with carbaryl. Each seedling was thoroughly inspected for new bore sites on a weekly basis; borer holes were flagged and recorded. The seedlings were inspected for physical damage (i.e. broken stems, dead leaves) on a daily basis. Carbaryl was reapplied in November 2013. Damage from the black twig borer occurred within a few days of being outside and has continued to date. Phytotoxicity was observed on the seedlings treated with carbaryl, including leaf burning, stem dieback and seedling mortality. Monitoring will continue in 2014. This work is supported by Forest Health Protection Special Technology Development Program funds.

Koa Moth (*Scotorythra paludicola*): The koa moth (or koa looper) is an endemic insect on the islands of Hawai'i, Maui, and O'ahu. The caterpillars feed only on *Acacia koa* leaves and are capable of defoliating mature koa trees. Population explosions have been documented historically on Maui and Hawai'i islands, where large areas of koa forest have been defoliated. In 2013, an island-wide outbreak occurred on Hawai'i island defoliating approximately 70,000 acres of koa forest. This is the most expansive outbreak of koa moth ever recorded.

The moths and caterpillars are normally present at low levels in koa forest. Young caterpillars feed by scraping the surface of phyllodes (often referred to as mature koa "leaves"), producing scars that start out light green and turn brown as the tissue dies, giving the phyllodes a splotchy appearance. Older caterpillars are able to chew through whole phyllodes, causing chewing damage along the margins. The caterpillar stage lasts about a month, followed by a pupation stage of 10-12 days. Adults live for weeks, are usually active at night, and are believed to lay their eggs under bark and in patches of moss on koa trunks. Swarms of females



Koa looper caterpillar. (W. Haines)



Koa forest defoliated by the koa looper. (W. Haines)



Refoliated koa branches. (J. B. Friday)

far from defoliated areas, suggesting the ability to disperse to new food sources. The full life cycle lasts about 2 months.

In January 2013, DLNR staff reported severe defoliation of koa forests above Hilo. In late January, aerial surveys identified the likely causative agent as *Scotorythra paludicola*, and documented severe defoliation from Wailuku River to Laupahoehoe. Subsequent ground surveys at Humu'ula Trail identified a "satellite" area of defoliation there. By May 2013, within a matter of months, the moth outbreak had spread all over Hawaii Island, affecting most of the large tracts of koa-dominated forest on the island. As the moth spread from the original outbreak, the infestation became patchier.

As early as May 2013, trees were observed refoiliating in the infestation area. In some instances trees were defoliated again by outbreaking caterpillars. There was one report of trees being defoliated a third time. While caterpillar activity has ceased in most koa forests, above normal caterpillar activity is still occurring at some sites. Causes for the collapse of the moth population are unknown. Several non-native parasitoids have been identified both in the field and from rearing caterpillars in the lab, but they have not been observed at levels high enough to exert wide-scale control.

The acacia psyllid (*Acizzia uncatoides*), a pest introduced to Hawaii in the 1960's which feeds and breeds on the young terminals of koa, has been observed in recovering koa forests. Psyllid populations are known to closely track koa flushing, and could hinder forest recovery seen in past outbreaks where it was not present. So far the psyllids do not appear to be preventing koa recovery but monitoring is ongoing. Other negative interactions from the outbreak include the invasion of introduced plants into the understory limiting regeneration of native forest species.

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



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

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 *Quadrastichus 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 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 Hawai'i'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 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 will 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,

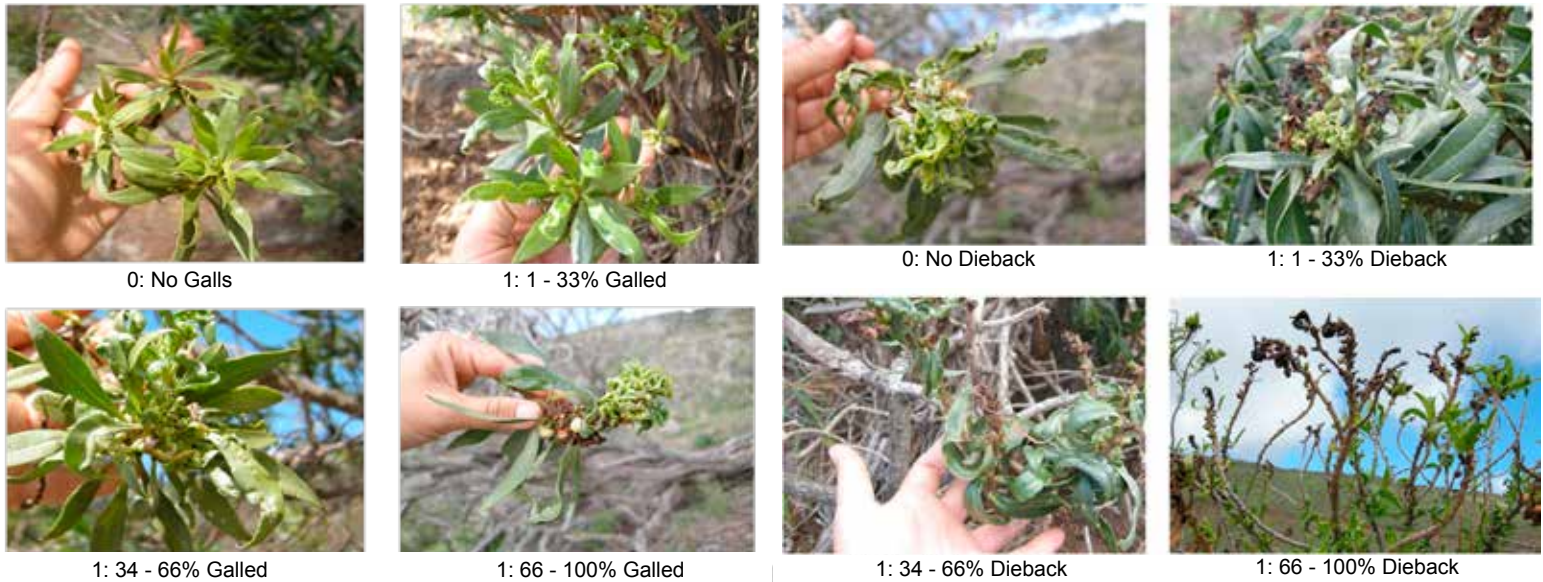


Fig. 1 Infestation scale used in field monitoring of young tissue.

Fig. 2 Dieback scale used in field monitoring.

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 objectives were 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.

Monitoring Results: Naio trees are experiencing tree mortality, which has increased over the past three years of monitoring at 6 sites (Fig. 3). Thrips feeding causes gall-like symptoms and kills foliar tissue. Severe infestations can lead to branch die-back and ultimately to tree mortality. During monthly site visits, young shoots and branches were rated for infestation and dieback using a four point scale (Fig. 1 & 2). Data from three years of monitoring show that the infestation level in leaves increased considerably and that infestation levels are higher at medium elevation sites. Similarly, dieback levels increased considerably during the three year monitoring period, and were also higher at medium elevation sites (Fig. 4).

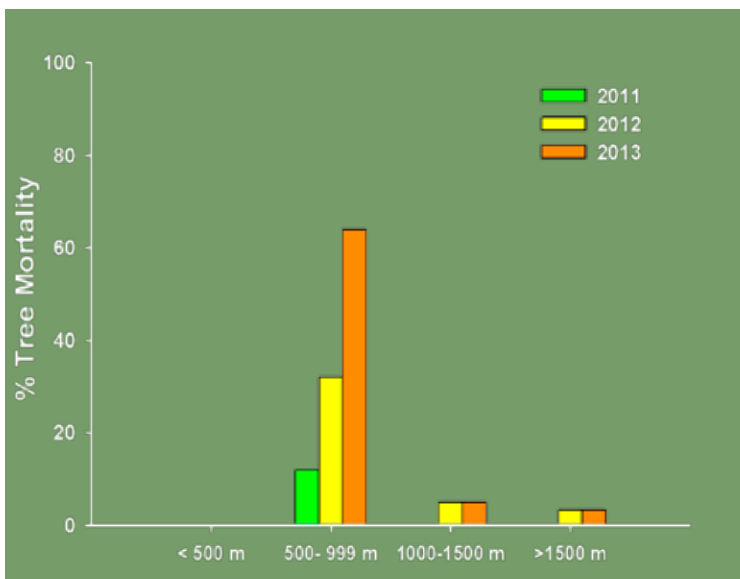


Fig. 3 Tree Mortality

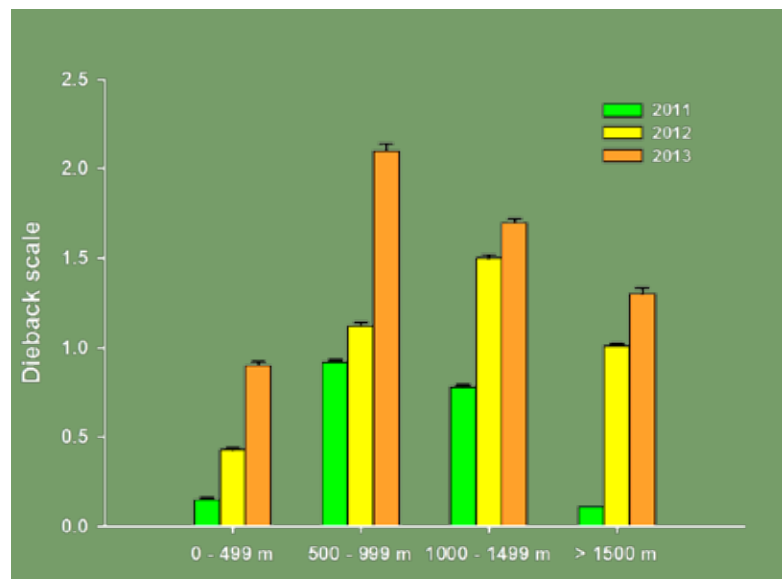


Fig. 4 Branch Dieback Rates

Invasive Plants

Devil Weed

Chromolaena odorata

Chromolaena odorata, also known as Devil weed, is a state-listed noxious weed that is toxic to other plants, livestock and humans. It possesses the ability to root vegetatively, produces wind-dispersed seeds, and is a fire promoting species that forms dense, monotypic stands of vegetation limiting forest regeneration. The US Army's natural resource program discovered *C. odorata* at the Kahuku Training Area (KTA) on the north shore of O'ahu in January 2011.

It is highly likely the pathway of introduction to KTA was military activities. Between 2006 and 2009, botanical surveys of all publicly accessible roads on O'ahu were conducted by Oahu Invasive Species Committee's Early Detection program. *C. odorata* was not found during these surveys despite being on the target list. *C. odorata* is a major pest on the island of Guam, and units from Hawai'i sometimes train in Guam. The seeds readily attach to clothing, and one plant can produce approximately 800,000 seeds a year.

In 2013, OISC conducted surveys and treatments for Devil weed at KTA in partnership with the Hawai'i Department of Agriculture and the O'ahu Army Natural Resources Program. The OISC field crew conducted delimiting surveys to determine population distribution and density in the Kahuku region. Two new satellite populations have been found on the island and are being controlled. OISC continues to survey and treat this species, but eradication is appears unlikely, and opportunities for biological control are being investigated.



Mature Devil weed in the Kahuku Training Area

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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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