Multi-Threat Control Strategies for Endangered Species Management on O‘ahu Army Lands in Hawai‘i

Jane Reppun Beachy[1,2], Stephanie Joe[1,2], Stephen Mosher[1,2], H. Kapua Kawelo[1], Jobriath Rohrer[1,2], Matthew Keir[1,2], Matthew Burt[1,2], Vince Costello[1,2], Michelle Mansker[1], Dan Sailer[1,2], Krista Winger[1,2], Lalasia Bialic-Murphy[1,2]

[1]O‘ahu Army Natural Resources Program, Department of the Army USAG-HI, Directorate of Public Works, Environmental Division, Natural Resources, (IMPC-HI-PWE), 947Wright Avenue, Wheeler Army Airfield Schofield Barracks, HI 96857-5013; jane.beachy@us.army.mil

[2]O‘ahu Army Natural Resources Program, Pacific Cooperative Studies Unit, Botany Department, University of Hawaii Manoa, 3190 Maile Way, St. John Hall #408, Honolulu, HI 96822-2279

ABSTRACT

The U.S. Army Garrison Hawai‘i is required to manage 67 endangered taxa, including 51 plants, nine tree snails, one bird species, and potentially six picturewing flies on the island of O‘ahu, Hawai‘i. These species occupy fragmented, disturbed habitat and face multiple threats. The O‘ahu Army Natural Resources Program (OANRP) manages these species across 56 geographically defined Management Units (MUs). Located on the rim of Mākua Valley, the Kahanahāiki MU encompasses 90 acres of mixed native/invasive mesic forest and is home to one tree snail species and both wild and reintroduced populations of 10 endangered plant taxa, including *Cyanea superba* ssp. *superba*, which was extirpated from the wild in 2003. Threats include feral pigs, black and Polynesian rats, mice, weeds, snails, slugs, and arthropods. The goal of threat control is to restore habitat in the MU such that endangered taxa thrive and maintain viable, stable populations. Multiple threats must be controlled simultaneously to achieve this goal. Feral ungulates were successfully excluded from the area in 1997 via fencing and snaring. A large snap trap grid, installed in early 2009, maintains low numbers of rodents. Weeds are primarily managed around rare taxa, although more aggressive restoration projects seek to create more continuous native forest. Both incipient and established weeds are controlled. Invasive slugs, predators of native seedlings, are controlled using a natural product containing iron phosphate. Native tree snails are protected from the carnivorous snail *Euglandina rosea* via multiple barrier (salt, electricity, overhang) exclosures. Experiments to detect *E. rosea* using dogs are ongoing. Ant surveys allowed for the detection and eradication of an incipient population of *Solenopsis geminata*. Black twig borer traps are deployed around endangered trees. Rare taxa are responding to these efforts; in 2009, wild seedlings of *C. superba* were documented for the first time in over 30 years.

THREATS

UNGULATES: PIGS (*Sus scrofa*)

Threat Level: HIGH
Seasonality: Year round
Control Level: Across Management Unit
Acceptable Level of Activity: 0

Resources Threatened/ Damage Observed

- Pig wallows, trails, digging, feeding all impact Hawaiian ecosystems, which evolved in the absence of ungulates.
- General ecosystem integrity, especially vegetation health, is heavily affected by pigs.
- Habitat for endangered plants; all taxa at risk, although gulch dwelling species most affected.
- Habitat for endangered tree snails, *Achatinella mustelina*.

Control Methods

- Fence construction/ pig exclusion
- Transects, to detect activity level along fence, potential fence breaches
- Snares, to reduce pig pressure on the outside of the fence

Current Status

- Subunit I fence pig-free since 1998.
- Transects along fence line monitored quarterly.
- 57 snares deployed in high activity zones in Subunit 2

Planned Actions

- Maintain Subunit I fence.
- Construct Subunit II fence; eradicate pigs from area using combination of hunting and snaring.
- Monitor fenceline transects quarterly to detect pig activity level along fence, potential breaches, and damage from severe weather.
- Continue using snares in Subunit II to protect Subunit I. When Subunit II fence complete, reevaluate need for snares.

Measures of Success

- Endangered species recovery

Reintroduced *C. superba* are circled in red

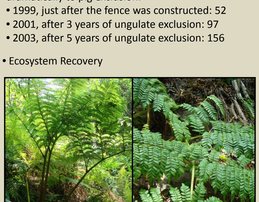
Many rare plants known to be susceptible to pigs are now thriving. This includes reintroductions of *Cyanea superba* subsp. *superba*, and *Cenchrus agrimonioides* var. *agrimonioides*.

Reintroductions of both species have high survivorship, and seedlings have been observed.

The gulch habitat of *Cyrtandra dentata* was heavily impacted by pigs; #s of mature plants responded dramatically to pig exclusion.

- 1999, just after the fence was constructed: 52
- 2001, after 3 years of ungulate exclusion: 97
- 2003, after 5 years of ungulate exclusion: 156

- Ecosystem Recovery



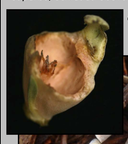
The general plant community response to pig removal has been positive. Large starchy ferns such as *Cibotium* sp. and *Marattia douglasii*, which were targeted by pigs, are now thriving in the gulch.

RODENTS: RATS (*Rattus rattus, R. exulans*)

Threat Level: HIGH
Seasonality: Year round
Control Level: Across Management Unit
Acceptable Level of Activity: 10%

Resources Threatened/ Damage Observed

- Rats consume *Achatinella mustelina*, an endangered tree snail. Kahanahāiki is home to a large population of 300 snails.
- Eggs of the ‘elepaio, or *Chasiempis sandwichensis* subsp. *ibidis*, a Hawaiian flycatcher, is predated by rats.
- Rat damage has been observed on fruit, seeds, meristems, and bark of a variety of common and rare plants.
- Select endangered plant taxa are particularly susceptible to rat damage: *Cyanea superba* subsp. *superba, Schiedea obovata,* and *Delissea waianaensis*.



C. superba fruit with rat chew

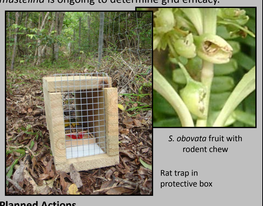
Rat predated *A. mustelina* shells

Control Methods

- OANRP is following New Zealand DOC Best Practices for snap trap grids.
- Population suppression via a grid of covered snap traps encompassing all of Subunit I and part of Subunit II.
- Activity-level monitoring with tracking tunnels.

Current Status

- Pilot project grid of 440 traps installed May 2009. The grid protects 90 acres and is checked 1x or 2x a month, depending on rat seasonality.
- Tracking tunnels are monitored monthly.
- Monitoring of seed rain, seedling recruitment, alien slug and snail populations, arthropods, and *A. mustelina* is ongoing to determine grid efficacy.



S. obovata fruit with rodent chew

Rat trap in protective box

Planned Actions

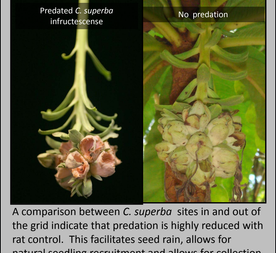
- Maintain snap trap grid.
- Monitor rat activity with tracking tunnels
- Continue monitoring of ecosystem response variables to rat control
- Fine tune grid layout, trap density, and re-bait frequency to maximize efficacy
- Develop more effective bait (peanut butter)

Measures of Success

- Endangered species recovery

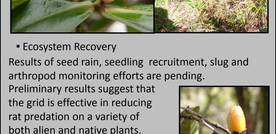
Healthy *S. obovata*

Stems and fruit of *S. obovata* occasionally were chewed by rats and/or mice. No chew has been observed since the pilot project grid was installed.



A comparison between *C. superba* sites in and out of the grid indicate that predation is highly reduced with rat control. This facilitates seed rain, allows for natural seedling recruitment and allows for collection of seed for genetic storage, propagation, and reintroduction.

No rat predated shells have been found during monitoring of ground shell plots.



- Ecosystem Recovery

Results of seed rain, seedling recruitment, slug and arthropod monitoring efforts are pending.

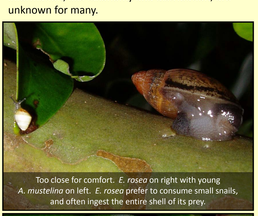
Preliminary results suggest that the grid is effective in reducing rat predation on a variety of both alien and native plants. This includes the weed *P. cattleianum*, and native taxa *Diospyros sandwicensis* and *Nestigis sandwicensis*.

CARNIVOROUS SNAILS (*Euglandina rosea*)

Threat Level: HIGH
Seasonality: Year round
Control Level: Across Management Unit
Acceptable Level of Activity: Unknown

Resources Threatened/ Damage Observed

- *E. rosea* attack *Achatinella mustelina*, an endangered tree snail. Kahanahāiki is home to a relatively large population of 300 snails.
- *E. rosea* may also consume other native snails. Many native snail species are poorly studied. Basic information, like taxonomy and distribution, are unknown for many.



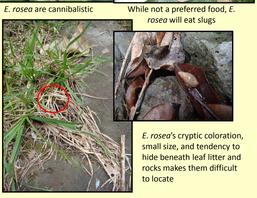
Too close for comfort. *E. rosea* on right with young *A. mustelina* on left. *E. rosea* prefer to consume small snails, and often ingest the entire shell of its prey.

Adult and subadult *A. mustelina* from Kahanahāiki.

Adult snails are larger than 18mm, subadults between 8-18mm, and juveniles less than 8mm.

E. rosea are cannibalistic

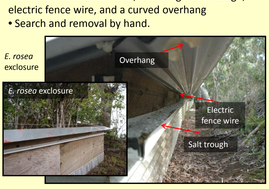
While not a preferred food, *E. rosea* will eat slugs



E. rosea’s cryptic coloration, small size, and tendency to hide beneath leaf litter and rocks makes them difficult to locate

Control Methods

- No effective chemical control methods exist.
- Physical barriers/ exclosures. Current barriers include *E. rosea* deterrents, including a salt trough, electric fence wire, and a curved overhang
- Search and removal by hand.



Current Status

- While the current design for physical barriers is effective, existing exclosures are difficult to maintain, artificially separate *A. mustelina* breeding populations, and only protect small areas.
- OANRP is investigating alternative physical barrier designs to reduce maintenance needs.
- A pilot program testing the potential for working dogs to detect *E. rosea* is ongoing. Early results suggest that *E. rosea* is a difficult target. Surveys by staff were as effective at finding snails as surveys by dogs. However, adjustments to training techniques and greater exposure to *E. rosea* may improve dogs’ detection ability.

Working Dogs for Conservation, based out of Montana, was hired to determine whether *E. rosea* are detectable by dogs.

Physical barrier designs undergoing testing

Planned Actions

- Continue testing physical barriers.
- Continue pilot trial with snail-detecting dogs.
- Perform hand removal around *A. mustelina* sites.

Measures of Success

- Endangered species recovery

It is difficult to measure success, as *E. rosea* predation is spotty and inconsistent. A single *E. rosea* may wipe out dozens of *A. mustelina*.

Monitoring of *A. mustelina* inside the *E. rosea* exclosure indicates that snail populations have remained stable since it was built in 1998. No *E. rosea* have ever been found in the exclosure.

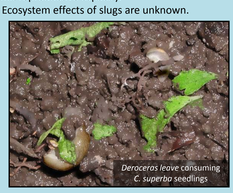
Mark recapture snail monitoring tools

SLUGS (*Deroceras leave, Limax maximus, Limax flavus, Meghimatium striatum)*

Threat Level: HIGH
Seasonality: Wet season
Control Level: Localized
Acceptable Level of Activity: Unknown

Resources Threatened/ Damage Observed

- Studies indicate that certain plant families are highly susceptible to slugs, in particular Campanulaceae and Caryophyllaceae.
- Endangered taxa in these families are *Cyanea superba* subsp. *superba, Schiedea obovata, S. nuttalii,* and *Delissea waianaensis*.
- Slugs are seedling predators. They have a significant negative impact on seedling survival for both *C. superba* and *S. obovata*.
- Slug damage has been observed on stems and apical meristems of certain plants. This damage is not always fatal, but may reduce plant health and limit reproductive capacity.
- Ecosystem effects of slugs are unknown.



Control Methods

- No U.S. government approved control methods exist.
- OANRP is working towards the development of a control method. A pilot project evaluating the efficacy and feasibility of Sluggo® as a means of eliminating slugs in native forest is underway.
- Sluggo® is an organic molluscide with the active ingredient iron phosphate. It has no affect on birds, mammals, fish, or other invertebrates. It is ingested orally and interferes with proper digestion, causing death in 48-72 hours.
- Sluggo® may kill native snails.
- Beer traps and physical barriers of copper/zinc are labor intensive, expensive and have only limited efficacy.

Current Status

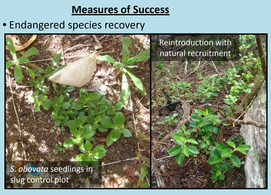
- Research completed by OANRP indicates that Sluggo® is effective at killing slugs and has a postitive effect on seedling survival.
- Permitting is being pursued with the Environmental Protection Agency to register Sluggo® for use in forestry settings in Hawai‘i. Trials are carried out under an Experimental Use Permit overseen by the Hawai‘i Dept. of Agriculture.
- Sluggo® should *not* be deployed in proximity to trees harboring endangered tree snails, such as *A. mustelina*.
- Trials with Sluggo® continue around *C. superba* reintroductions to determine optimal application frequency.

Planned Actions

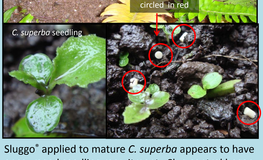
- Continue trials and pursue Sluggo® permitting.
- Track seasonal changes in slug densities
- Ensure bait does not harm *A. mustelina*.

Measures of Success

- Endangered species recovery



S. obovata seedlings are rarely observed. Sites where natural recruitment occurs tend to be dry and unlikely to harbor large numbers of slugs. Sluggo® applied to a distance of 15 m from sown *S. obovata* seeds led to significantly greater germination and survival of seedlings compared to a control group exposed to slugs under natural conditions.

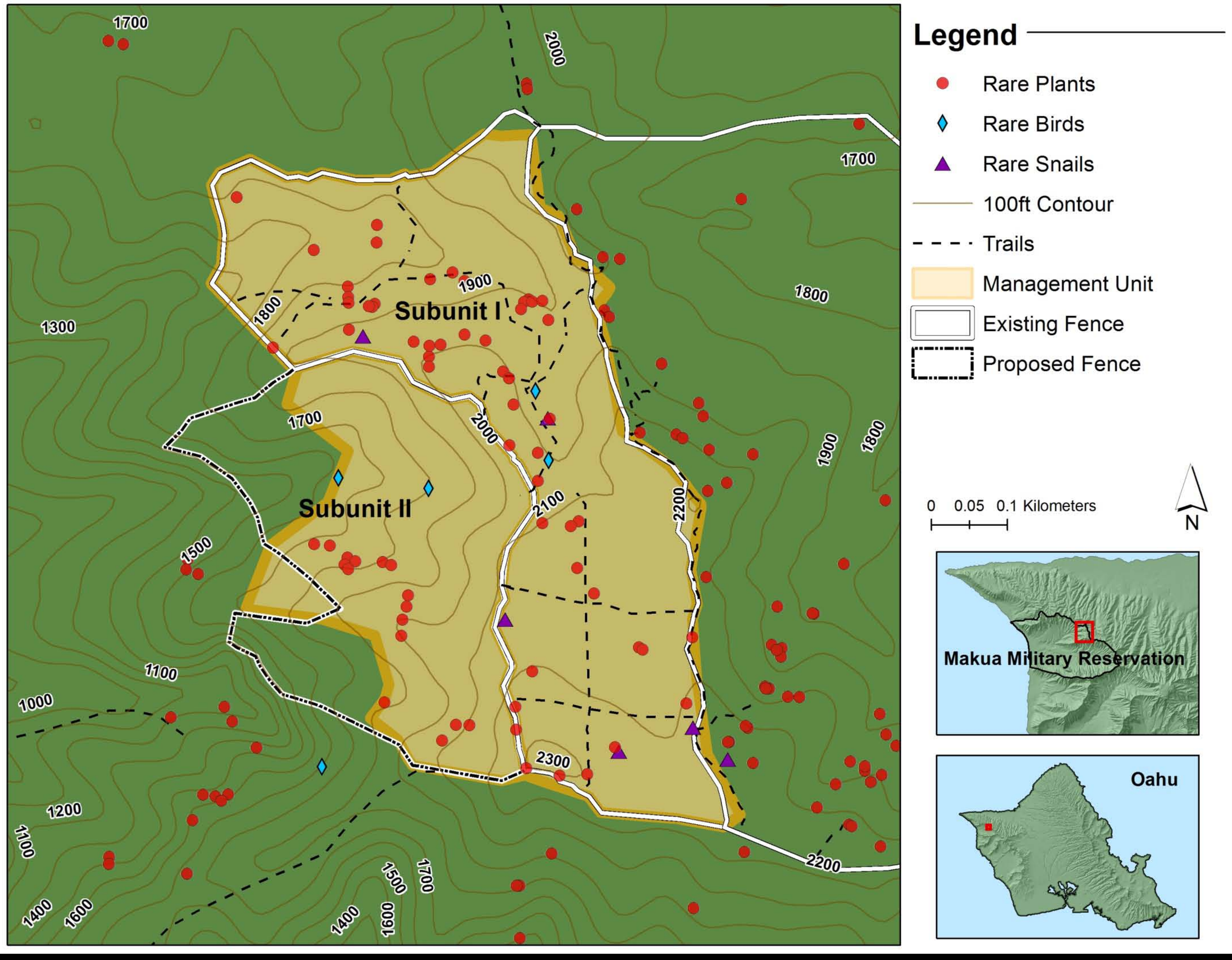


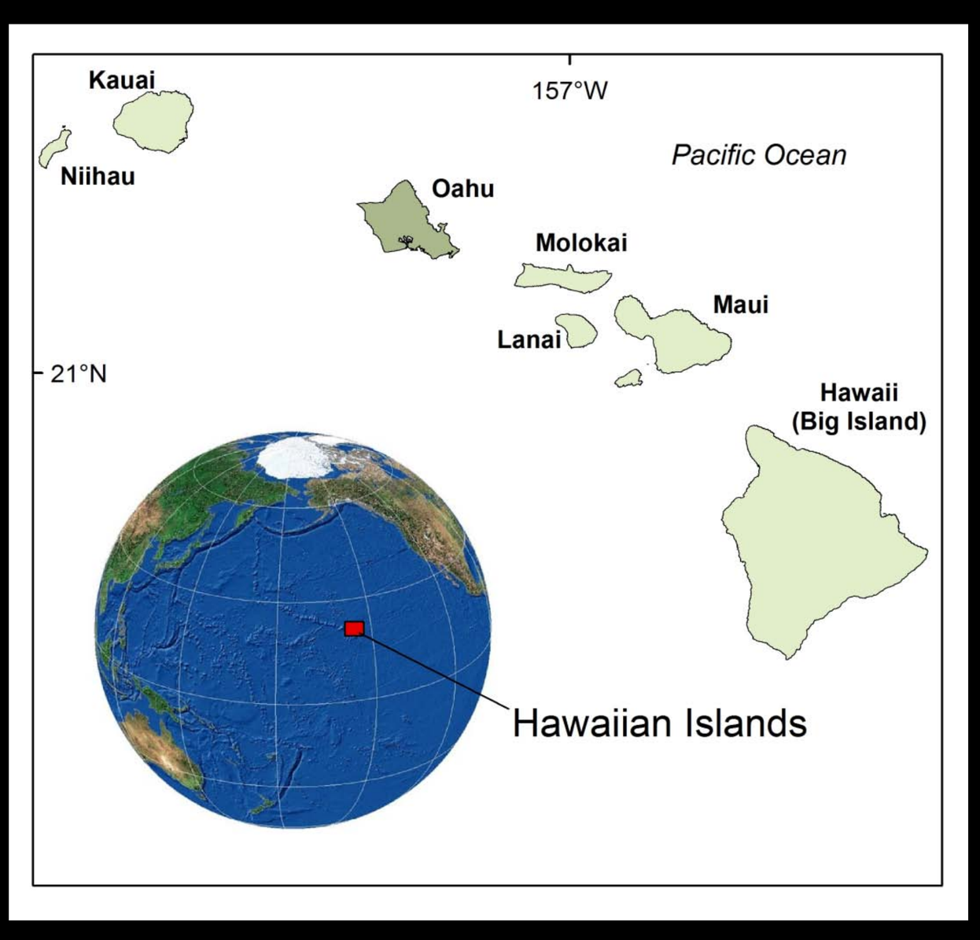
Sluggo® applied to mature *C. superba* appears to have encouraged seedling recruitment. Slug control began after fruiting in 2009 and continues today. More than 200 seedlings are extant, likely due to these efforts.

C. superba Population Status and Threat Control

- Late 1990’s: Last known wild plants found in Kahanahāiki. Plants protected from ungulates by a small fence. Seasonal rat control conducted to facilitate fruit collection.
- Nov. 1999: 6 plants left.
- Jan. 2003: last plant dies.
- Seed collected from wild plants is used to propagate *C. superba* in the greenhouse.
- 1998: *C. superba* first reintroduced to Kahanahāiki exclosure.
- By 2009, 387 plants reintroduced to Kahanahāiki
- 2004: first fruit found on reintroduced plants
- Recruitment of seedlings observed March 2009

Kahanahāiki Management Unit





Mākua Military Reservation, Northern Wai'anae Mountains, O'ahu

Size: 42 hectares

Elevation Range: 1400ft – 2300ft (427m-701m)

Description: Mesic, mixed alien and native vegetation. North and east aspects favor native forest remnants, while south and west aspects are weed-dominated. Managed since 1995. Threats include pigs, weeds, rats, carnivorous snails, slugs, and various arthropods. The Management Unit is made up of two Subunits

Rare resources:
18 taxa
(17 listed as endangered,
1 as a species of concern under the
United States Endangered Species Act)

Rare Plants	Rare Plants	Rare Plants	Rare Snail
Alectryon macrococcus var macrococcus	*Hedyotis degeneri var. degeneri*	*Diellia falcata*	*Achatinella mustelina*
Cenchrus agrimonioides var. agrimonioides	*Nototrichium humile*	*Euphorbia haeleeleana*	
Cyanea superba subsp. superba	*Schiedea nuttallii*	*Lepidium arbuscula*	
Cyrtandra dentata	*Schiedea obovata*	*Pteralyxia macrocarpa*	
Delissea waianaensis	*Alphitonia ponderosa*	Rare Bird	
Flueggea neowawraea	*Bobea sandwicensis*	*Chasiempis sandwichensis subsp. ibidis*	

THREATS

WEEDS
(multiple species)

Threat Level: HIGH
Seasonality: Year Round
Control Level: Both Across the MU and Localized
Acceptable Level of Activity: Unknown

Psidium cattleianum *Clidemia hirta* *Schinus terebinthifolius*

Resources Threatened/ Damage Observed

- Alien plants can drastically alter environmental conditions, including nutrient cycles and moisture.
- Different weed species have different effects.
- Weeds displace native taxa. Some compete with native plants for resources.
- Certain highly invasive taxa, such as *Psidium cattleianum*, form monocultures which exclude almost all other species, native and alien alike.
- The loss of native host plants can be catastrophic for arthropods and snails which depend on them exclusively or preferentially.
- The influx of alien grasses favors fire regimes.

P. cattleianum removal

Control Methods

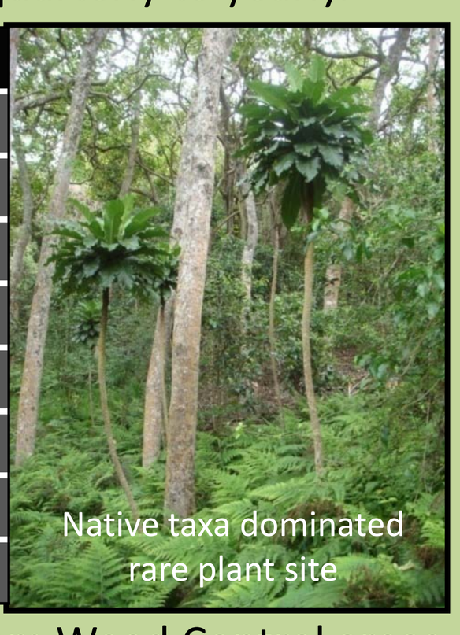
- Weed control efforts at Kahanahāiki are divided into 4 main categories: Vegetation Monitoring, Surveys, Incipient Taxa Control, and Ecosystem Management Weed Control.
- Vegetation monitoring involves systematic monitoring of the entire Subunit I area. The data collected allow staff to determine the composition of the area and gauge effectiveness of control efforts on a broad scale.
- Surveys are conducted around highly trafficked areas to detect incipient weed species which may move into the area. Helicopter landing zones and fencelines are surveyed quarterly. Incidental observations of weeds are noted during other control work.
- Incipient Taxa Control efforts target species which are not yet established in Kahanahāiki, with the goal of eradication. Achieving eradication is difficult, as many species form persistent seed banks.
- Ecosystem Management Weed Control efforts target specific locations in Kahanahāiki. These locations generally are native-dominated forest patches, rare plant sites (both wild and reintroduced), and occasionally weed-dominated forest patches where experimental control techniques are tested.
- Common native species plantings are used to complement weed control.
- Multiple control techniques are used to kill weeds. Basal, girdle, and cut stump applications of triclopyr are effective on a wide range of weeds. Foliar applications of glyphosate and fluazifop are effective on weedy grasses.

Reintroduced *Flueggea neowawraea* , circled in red, surrounded by alien weeds, particularly *Rubus rosifolius*.

Current Status

- Vegetation monitoring was completed in 2009. It will be conducted again in 2012.
- Despite its high diversity and concentration of endangered species, Kahanahāiki is home to many weeds. Alien cover is 35% of the understory and 53 % of the canopy.
- There are 19 different Incipient Control sites. Control frequency varies from quarterly to yearly.

Incipient Target Taxa	# of sites
Acacia mearnsii	2
Achyranthes aspera	3
Angiopteris evecta	1
Axonopus compressus	1
Casuarina glauca	1
Rubus argutus	2
Sphaeropteris cooperi	1
Triumfetta semitrilobata	8



Native taxa dominated rare plant site

- There are 14 different Ecosystem Weed Control areas. At some the goal is to achieve less than 25% alien vegetation cover. At others, it is to achieve less than 50% alien cover.
- Common native species trials are underway. These include: seed sowing, transplanting of seedlings from high density areas to open areas, and reintroduction of nursery-grown plants.

Bidens torta seed sow Clip and drip control Vegetation monitoring

Planned Actions

- Continue to carry out monitoring, surveys, and control efforts on a regular schedule. Weed control must be consistent to have lasting effect.
- Experiment with the use of a chipper to facilitate large scale clearing of *P. cattleianum* stands.
- Continue testing the efficacy of common native plantings and seed sows.
- Re-visit transect survey methodology to increase area monitored.

Measures of Success

- Future vegetation monitoring will show long-term effects of weed control.

Common reintroduction trials have identified several species which grow well with a minimum of care.

Acacia koa germinates prolifically after *P. cattleianum* removal

Planted *Microlepia strigosa* spreads to cover bare ground

Trials show that removal of *P. cattleianum* monocultures results in open areas which are colonized by native pioneers, particularly *A. koa* and *Scaevola gaudichaudii*.

ARTHROPODS:
BLACK TWIG BORER
(*Xylosandrus compactus*)

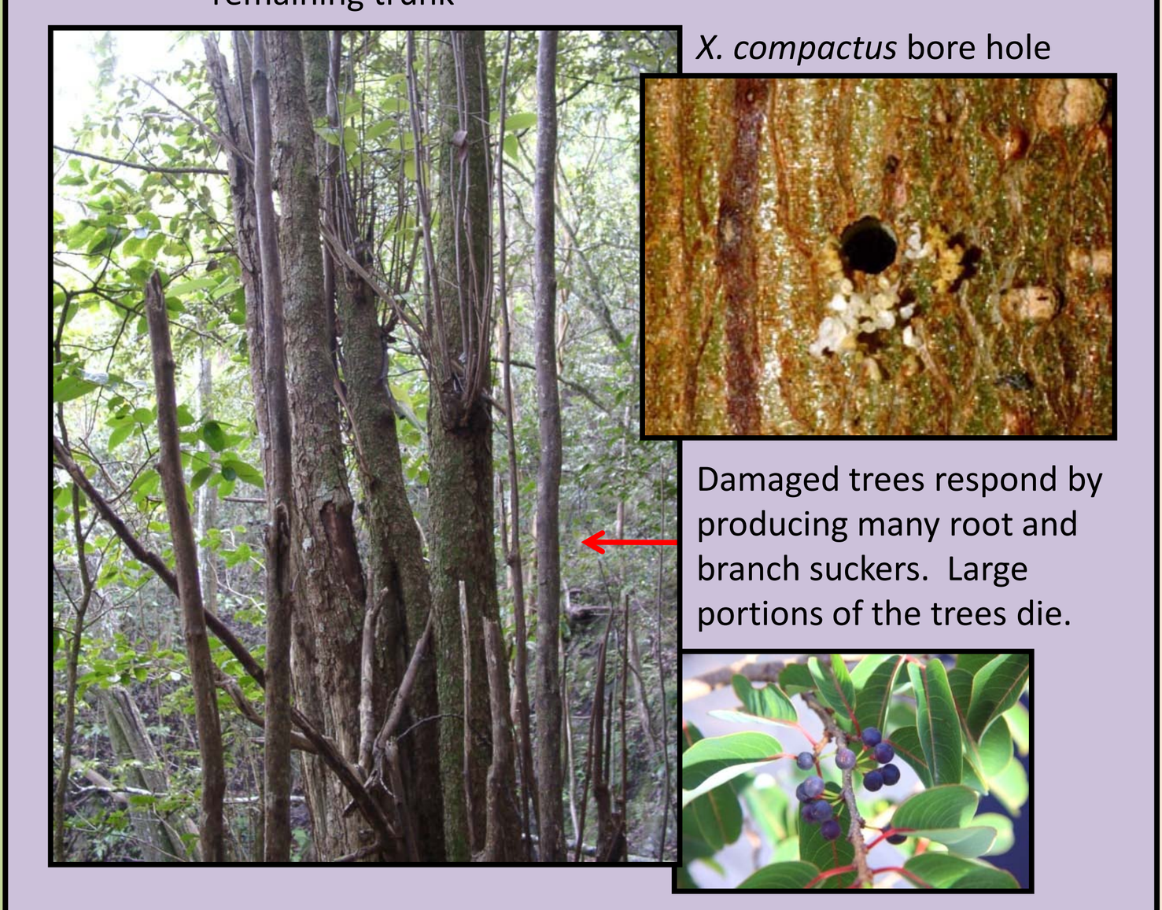
Threat Level: HIGH
Seasonality: Peak threat October - January
Control Level: Localized
Acceptable Level of Activity: Unknown

Resources Threatened/ Damage Observed

- Over 108 plant genera in Hawai'i are negatively affected by *X. compactus*. This includes both native and alien taxa.
- *X. compactus* attack live trees. Females bore holes into living tissue, forming galleries in which they lay their eggs.
- *X. compactus* also introduce potentially disease-causing strains of ambrosia fungus, upon which larvae feed.
- Devastating effects are seen on two highly endangered trees, *Flueggea neowawraea* and *Alectryon macrococcus*.

F. neowawraea in Kahanahāiki. Note wide stump and narrow remaining trunk

F. neowawraea were once the giants of the mesic forest



X. compactus bore hole

Damaged trees respond by producing many root and branch suckers. Large portions of the trees die.

Healthy foliage and fruit

Control Methods

- No effective insecticides are available for use in wild settings. Greenhouse trials of systemic insecticides resulted in increased health of potted plants. However application in the field is highly labor intensive and currently not allowed by the U.S. government.
- Manual removal is impossible, as *X. compactus* resides in plant pith.
- Thoughtful site selection for *F. neowawraea* reintroductions can affect survival. Planted in full sun, in mosit gulch bottoms, plant growth can outpace *X. compactus* damage.

Current Status

- Reintroductions of *F. neowawraea* are outplanted into gulch locations.
- The efficacy of high-release ethanol traps in reducing infection of *F. neowawraea* by *X. compactus* is being investigated. Results suggest that the lure traps may have resulted in lower rates of attack for some plants, but these findings are not significant.

Monitoring *F. neowawraea* for signs of *X. compactus* damage

High-release ethanol lure traps deployed around reintroductions

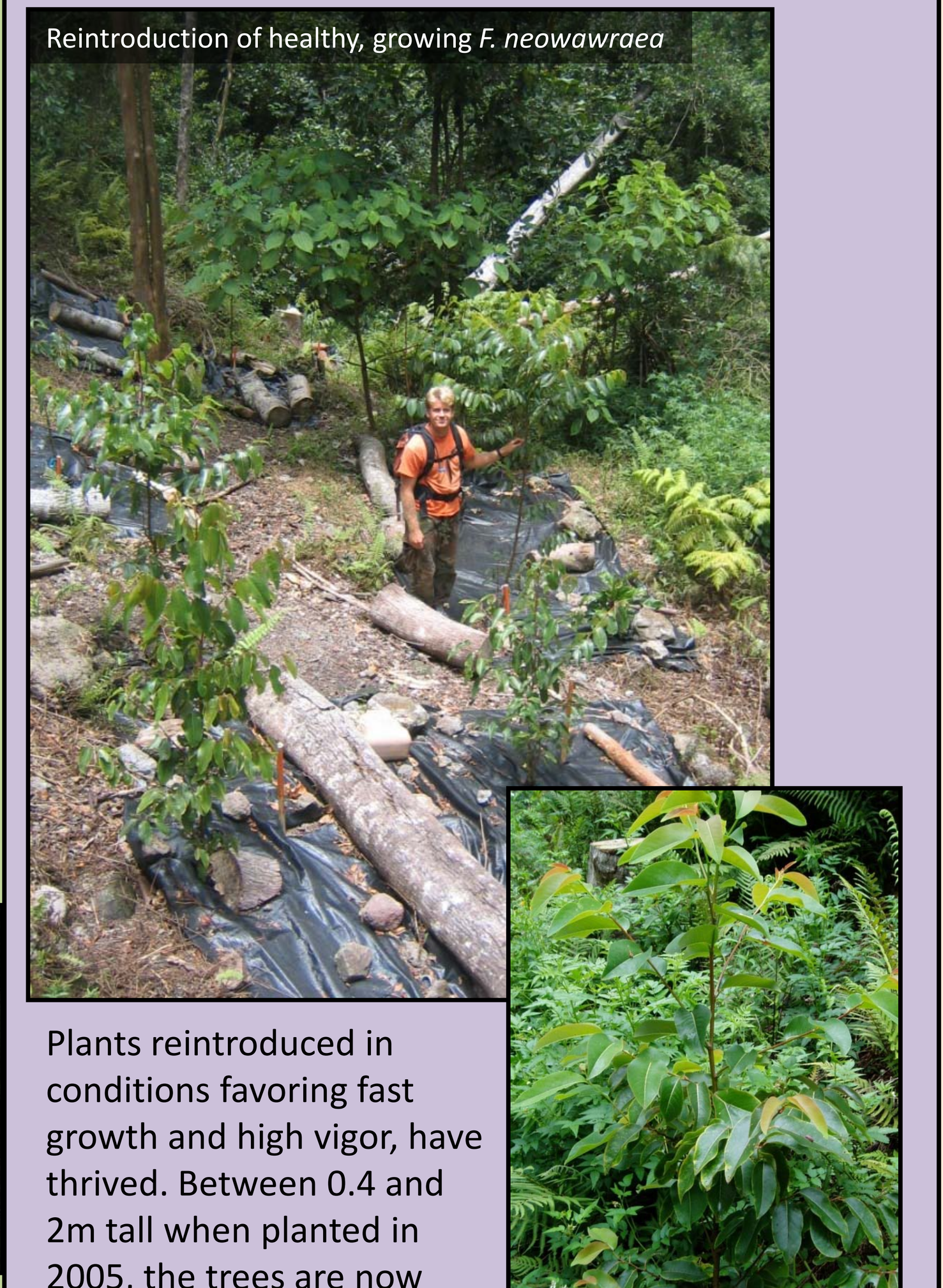
Planned Actions

- Monitor *X. compactus* damage to reintroduced *F. neowawraea*.
- Continue testing of high-release ethanol traps as small scale population sinks.
- Investigate the use of *X. compactus* repellants

Measures of Success

- Endangered species recovery

Reintroduction of healthy, growing *F. neowawraea*



Plants reintroduced in conditions favoring fast growth and high vigor, have thrived. Between 0.4 and 2m tall when planted in 2005, the trees are now between 0.5 and 8m tall (2009). Ethanol traps have had mixed success in reducing *X. compactus* damage.

ARTHROPODS: ANTS
(multiple species)

Threat Level: HIGH
Seasonality: Year round, nest expansion in fall/summer
Control Level: Directed at incipient species only
Acceptable Level of Activity: Unknown

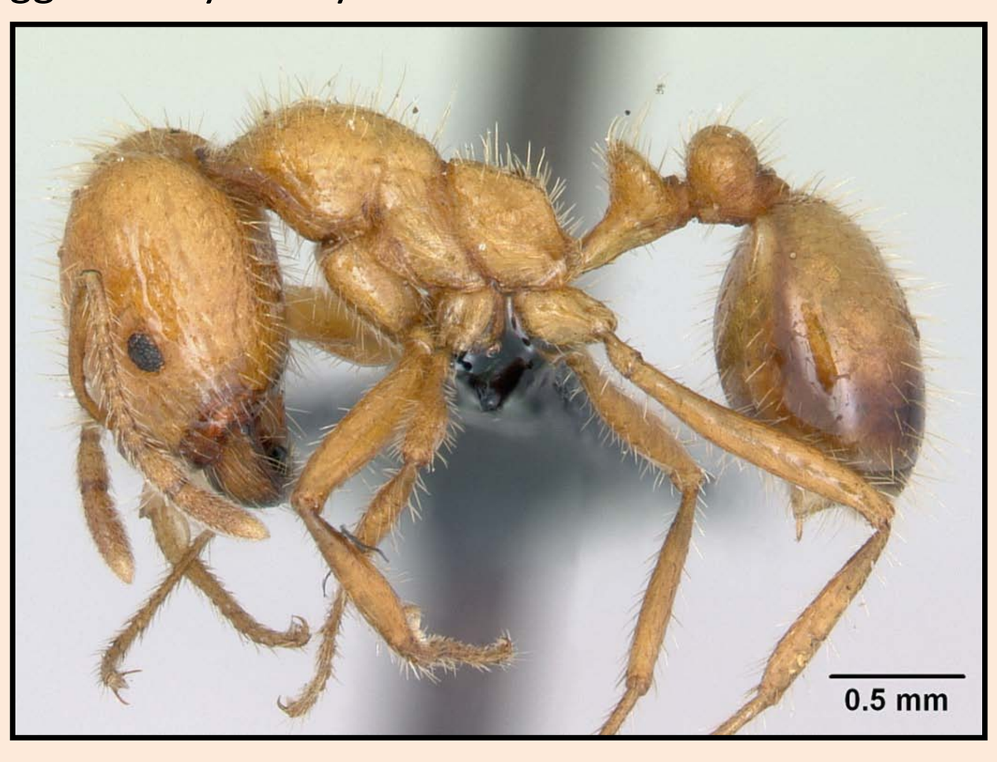
Hawai'i has no native ants.
Taxa found at Kahanahāiki include:
Anolepis gracilipes, Cardiocondyla emeryi, C. wroughtoni, C. venustula, Leptogenys falcigera, Ochetellus glaber, Plagiolepis alludi, Solenopsis geminata, S. papuana, Technomyrmex albipes, and *Tetramorium simillimum*

Resources Threatened/ Damage Observed

- Ants have been implicated in declines of native Hawaiian arthropods. They reduce populations of important pollinators such ground nesting bees (*Hylaeus*). Plants are further impacted by ants tending pests such as aphids and mealy bugs. Plants can have reduced seed set when ants damage flowers via nectar robbing.

Linepithema humile, an invasive ant on Maui, formerly found on Oahu, shown extracting honeydew from a scale insect. Photo by Alex Wild (myemecos.net)

- *Solenopsis geminata*, the tropical fire ant, has been present in Hawai'i for over 100 years. Like others in this genus, *S. geminata* is capable of delivering repeated, painful stings and can respond rapidly and aggressively to any disturbance.



S. geminata side view of worker. Photo courtesy of AntWeb.org

- Listed among the top five most invasive ants in Hawai'i, *S. geminata* is common in dry, disturbed areas below 450 m elevation. Thought to be restricted to lowland areas, in 2006 an isolated population was discovered in Kahanahāiki at 600 m elevation. The infestation encompassed an area 2,000 m².
- A number of other ant species were recorded from nearby areas in Kahanahāiki but not considered for eradication. They were either innocuous or too well established for treatment to be effective.

Area outlined in white shows the extent of the *S. geminata* infestation at Kahanahāiki in 2006

Control Methods

- Insecticides containing the active ingredient hydramethylnon (trade names MaxForce®, Seige® and Amdro®) have been shown to reduce forager numbers of several ant species and is approved for use in natural areas on Hawai'i.
- Survey protocol involves visual searches for nests and foragers, as well as the use of baits to attract nearby foragers (if present). Baits containing a source of protein (Spam®), fat (peanut butter) and carbohydrate (honey), placed on index cards, attract a range of ant species. Under warm and clear weather conditions when ants are active, cards are left under vegetation for 60 minutes, then retrieved. Any ants found are identified.

Current Status

- Surveys confirmed the extent of the *S. geminata* infestation soon after detection.
- Two applications of Amdro® (see table below) resulted in the eradication of this population.
- Continued monitoring elsewhere in Kahanahāiiki led to the discovery of a new *S. geminata* infestation, at another location in late 2009.

Solenopsis geminata **monitoring results pre and post treatment**

Date (2006) (MM/DD/)	# of baits with ants (of 40 total)	Visual search (2 person hours)	Notes
04/25	19	Present	
Treated on 05/30			
06/01	0	Absent	
06/05	0	Present	One nest found, but ants are behaving abnormally. Pupae present.
06/08	0	Absent	
06/15	0	Absent	
07/13	1	Present	Active nests found.
Treated on 07/24			
07/20	0	Absent	
07/27	0	Absent	
08/10	0	Absent	

Planned Actions

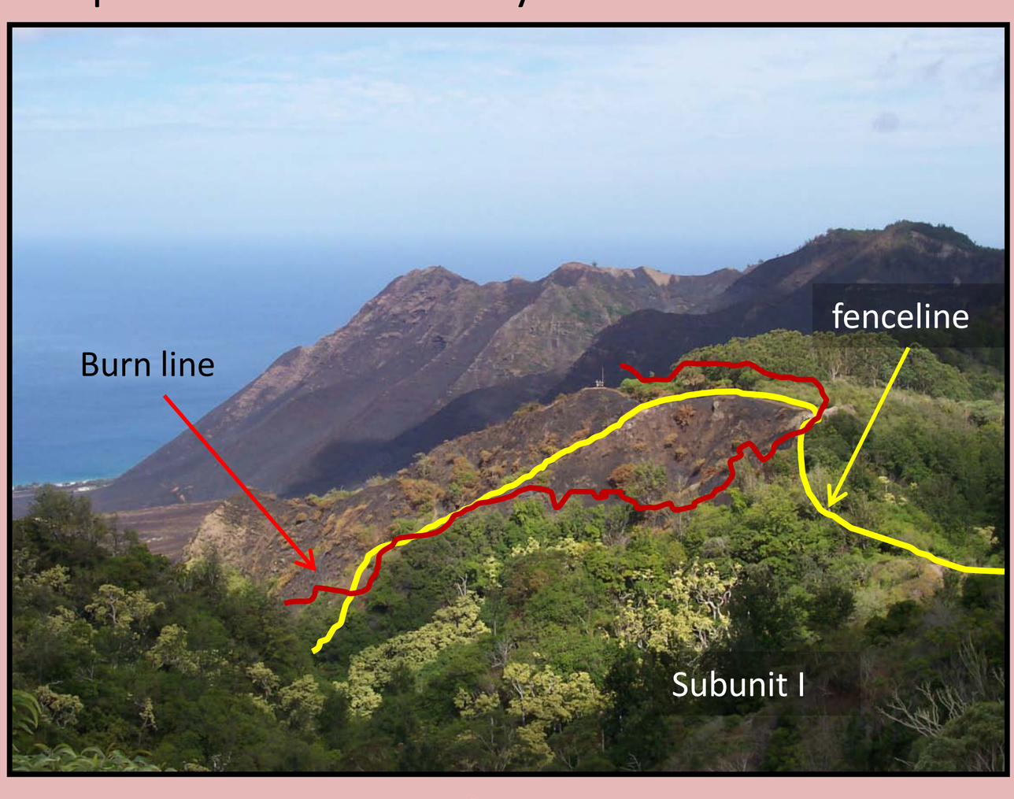
- Conduct quarterly surveys for ants across Kahanahāiki using bait cards. Detect new species, and new locations of known incipient species like *S. geminata*.
- Monitor density of established taxa using baits.
- Map the extent of the 2009 *S. geminata* infestation and commence treatment with Amdro®

Measures of Success

- Reduced numbers of foragers observed at baits
- Rapid detection of new species *S. geminata* in 2006 and 2009. Determination of furthest extent of infestation found in 2006.
- Extirpation of *S. geminata* from 2006 location.
- Continued absence of re-infestation at 2006 site.

FIRE
(Army training, arson)

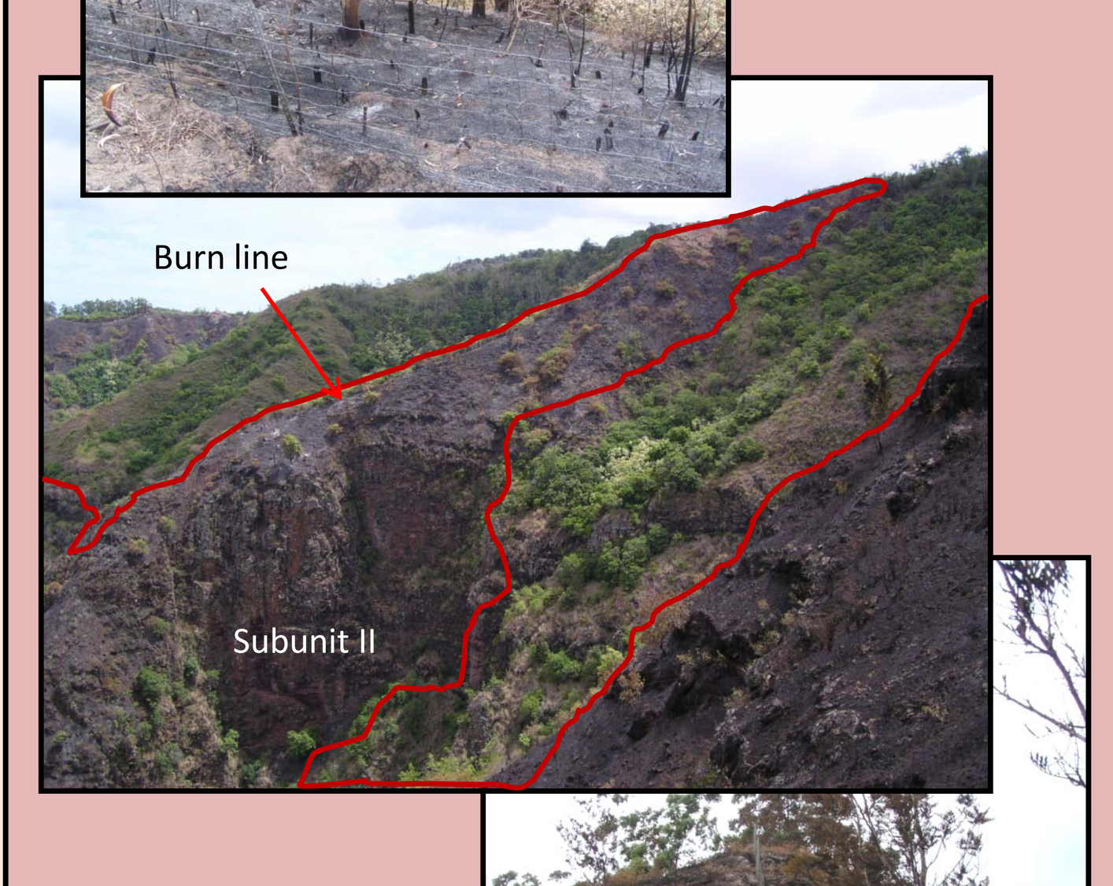
Threat Level: Low
Seasonality: Year round, primarily summer
Control Level: Across Management Unit
Acceptable Level of Activity: 0



Resources Threatened/ Damage Observed

- Hawaii's ecosystems are not adapted for fire. Thus, in a catastrophic fire, all native taxa suffer, common and rare, plants and snails.
- In 2003, a prescribed fire escaped fuel breaks and burned into both Subunits. While no rare taxa burned, the fire did come within 20m of one endangered plant site, burned common native forest, and damaged fencelines.
- Fires encroach on native forest and favor the recruitment of weedy grasses and other fire resistant alien taxa, increasing the probability and intensity of future fires.

Burned fence and native tree, *Acacia koa*



Burned fence loses its weatherized coating, increasing the potential for pig ingress and necessitating costly replacement

Control Methods

- Fire minimization measures are followed during Army training events.
- Training may only occur when environmental variables indicate that the likelihood of a fire is low. Weather stations deployed around the training range facilitate analysis of environmental conditions.
- Firebreaks ring the training area. Fuels (grasses) are kept to low heights within the fire breaks.
- OANRP communicates with Army Wildland Fire crews and Range Control staff to respond to fires.
- Helicopters are invaluable in fighting fire in steep, remote, dangerous terrain. Funds are reserved for this use.
- OANRP staff are trained to advise Fire Incident Command on strategy and rare species locations, and assist with mop-up activities, thus reducing the potential for flare-ups.
- OANRP participates in the Wildland Fire Working Group, a multi-agency group which collaborates on fire response, particularly to arson
- Landing zones and roads are maintained to facilitate access.
- Grasses are controlled in Subunit I.

Grass control

Helicopter water drops can be directed to protect resources

Staff conducting mop-up operations

Current Status

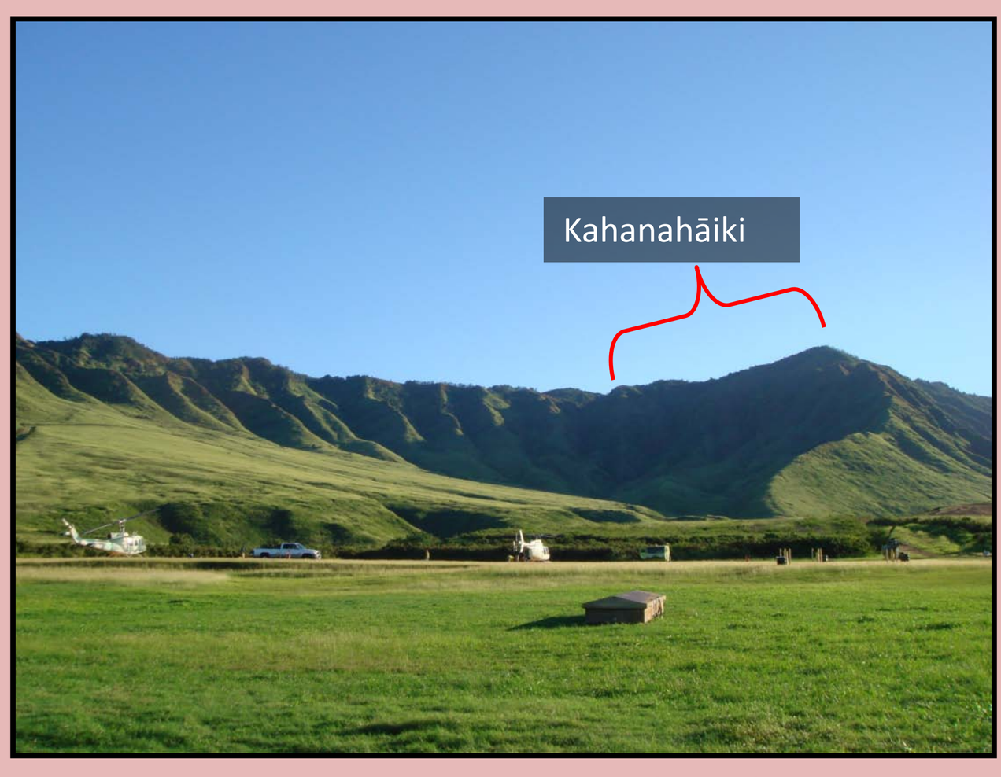
- OANRP currently are implementing all available control methods.

Planned Actions

- Continue to control grass within Subunit I.
- Expand grass control and reforestation efforts on the northwestern border of Kahanahāiki.
- Maintain communication with Army Wildland Fire and the Wildland Fire Working Group.
- Ensure staff receive refresher training in wildland fire reponse.
- Maintain helicopter landing zones , access roads.

Measures of Success

No fires have reached Kahanahāiki since 2003



Vegetation monitoring indicates that alien grass cover is 7.2% in Subunit I. Future monitoring will show effects of long-term control.

Mahalo nui loa
to all OANRP staff