“Invasive Species: Impact and Control”

Hawaii Pest Control Association Learning Conference

Ko`olina Resort
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The Hawaiian Islands

*Worst-case example of invasive species problem in the U.S and probably the entire world.

*Hawai'i's lush vegetation, warm temperatures and moderate humidity not only welcome tourist but provide a tropical paradise >1,000 invasive plants, vertebrates, and invertebrates

*Introduced from all corners of the world over the past 100 years.

20° N

The Hawaiian Islands

"Invasive Species Capital"

Why?

1. Island Ecology
2. Mild & Diverse Climate
3. Transportation Hub

20^{o} N

1. Island Ecology

* The most remote land mass in the world surrounded by a 2,500 mile ocean moat.
* Only several hundred species that arrived by ocean or air currents evolved into many thousands of native species.
* Native species are easily out competed by invasive species because they evolved without enemies.
* Hawaii has many unoccupied ecological niches where invasive plant and animal species could establish.

2. Mild & Diverse Climates

* Temperature at sea level ranges from 72 to 78^{o} F year round.
* Rainfall varies from 10 to 300 inches per year, creating highly diverse habitats.
* Eleven of 13 world climatic zones
* Elevation varies from sea level to 13,000 ft, from a tropical to temperate climate within 43 miles.

3. Transportation Hub

* HI residents rely on ships and air cargo for 98% of their goods.
* Hawaii imports goods from Asia and the Americas.
* Huge aircraft and ocean containers intentionally or unintentionally bring in hitchhiking species on cargo, plants and animals.

Spread of Invasive Species

by new cars

* Mazda recalled 65,000 Mazda 6 cars for 20 cases of yellow sac spiders nesting in fuel vent hoses (March 05. 2011, LA Times).

* A UC entomologist, John Trumble, says the infestation likely originated from the auto parts supplier warehouse before assembly.

* Madza disagrees, claims spiders were from the garages of owners after leaving the assembly plant.

Recent Invasive Species

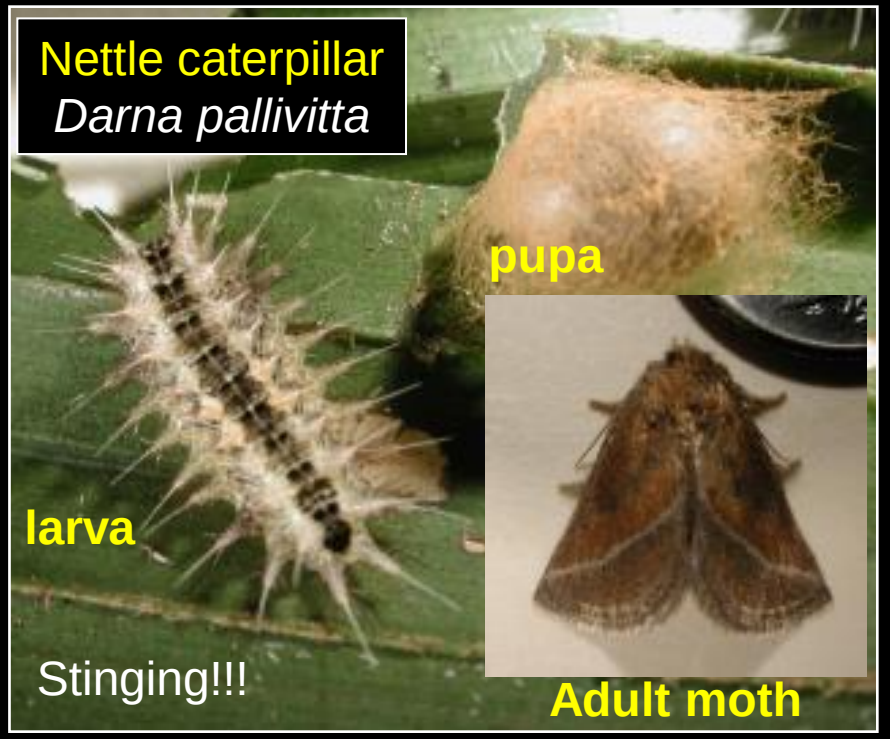
* Coqui frog from Puerto Rico -1999
* Little fire ant from S. America -1999
* Nettle caterpillar from Taiwan - 2001
* Privet whitefly from Neotropics -1998
* Giant whitefly from California - 2002

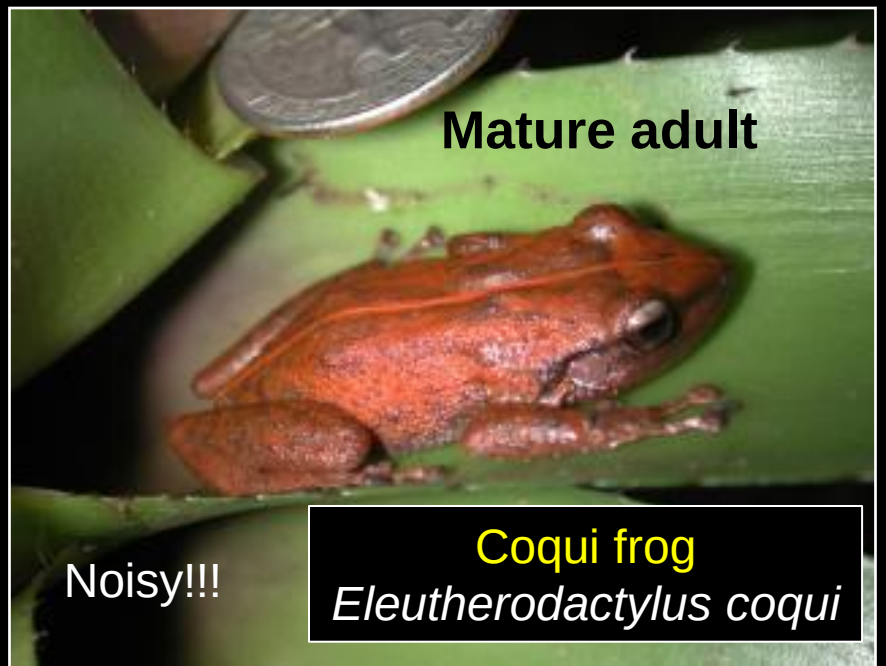
Giant whitefly
Aleurodicus dugesii

Privet whitefly
Aleurotrachelus trachoides

Little fire ant
Wasmannia auropunctata

Nettle caterpillar
Darna pallivitta





More Invasive Species Impacting Hawaii

White Peach Scale 1997

Cycad scale 1998

Cotton lace bug 2001

Varroa mite 2007
on honey bees

Papaya Mealybug 2004

Erythrina gall wasp 2004

Major Control Strategies for Invasives

Eradication – Fails; not attempted today. 18% success rate.

Containment – Intra-island and inter-island quarantines almost always fail.

Classical Biological Control – Very effective in the long-term, but there is a time lag.

Do Nothing – Fortuitous biological control is very effective in Hawaii.

– Invasive controlled by natural enemies (ne) that are also introduced with the pest or by existing (ne) in Hawaii.

Pest Management – Nonchemical and chemical controls

Invasive Species to be discussed:

* Coqui Frog
* Wiliwili Gall Wasp
* Nettle Caterpillar
* Giant Whitefly
* Slugs on X-mas Trees
* Snakes

Coqui frog, *Eleutherodactylus coqui* (Anura: Leptodactylidae)

* First reported in Hawaii in 1988, the coqui frog quickly adapted to Hawai'i from its native Puerto Rico and reached explosive numbers, with unlimited supply of food, habitats and the absence of predators and parasites.
* Male coqui have a high pitch loud “ko-kee” call that is considered melodious in Puerto Rico but disturbing in Hawaii, causing sleepless nights.
* The coqui frog is considered an interisland, interstate, and international quarantine pest in potted plants.

Life Cycle of the Coqui

* No tadpole stage: no need for free water, just moisture.
* Males exhibit parental care: Protect eggs from predators and diseases and keep eggs hydrated.

Egg cluster size:	34 (17-75)
Clusters/female/yr:	up to 26
Eggs incubation:	14 -17 days

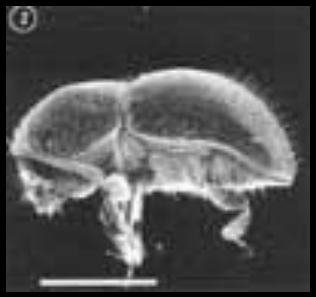
- Twelve months from egg to egg-laying adult.
- Adults live as long as 4 to 6 yrs.

What do coquis eat?

Millipeds
Ants
Honey bees
Snails
Spiders
Flies

Amphipods
Spiders
Beetles
Wasps
Wireworms
Mites

Anything that moves and bite sized!



*** Cannibalistic – Eats other coquis and their eggs!**
*** Can starve over 3 months and live on moisture only!**

Nesting Sites are Abundant in Hawaii

Lava rocks provide retreat sites

Frog activity increases during humid (>90%rh), warmer (> 80 F) periods, but they are capable of surviving temperatures between 45 and 102 F!

Control Strategies for Coqui Frogs

1. Chemical

2. Non-Chemical

All research in the world on tree frogs is on protecting declining populations and NOT control as an invasive species. WE WERE THE FIRST!

Chemical Controls

Citric Acid (Contact skin irritant)	Legal and effective in tests at (1.3 lb /1 gal. 16%). Burns certain foliage and flowers *(*ferns, orchids). Apply in the evening when frogs are active.
Pyrethrins (Nerve poison)	Will drive frogs out of hiding; they are able to detoxify and recover from this toxicant when applied alone.
Citric Acid + Pyrethrins	A combination of 8% citric acid + pyrethrins is effective, and will not injure plants.

Pyrethrins + Hydrated Lime Strategy

Paralyzed but not dead, may recover.

\+

=

Cannot recover and dies

Non-Chemical Controls

Cultural*	Habitat modification. Remove or minimize retreat and nesting sites.
Trapping*	Artificial PVC retreat and nesting sites
Biological*	Predators and diseases (chytrid fungus, rhabditid nematodes)
Irradiation	Sterilize frogs and release in population.
Genetic	Insert lethal or sterilizing gene into coqui frog population (long-term research)
Temperature*	Quarantine treatment for plants.
Heat	Hot water shower or vapor heat (113^{o} F)
Cold	In reefer at 42^{o} F for 3 days

*Further discussion

Habitat modification

Remove retreat and nesting sites

Before

After

Old leaves provide excellent retreat and nesting sites!

PVC Traps = “T” fitting and 8” length of vertical pipe

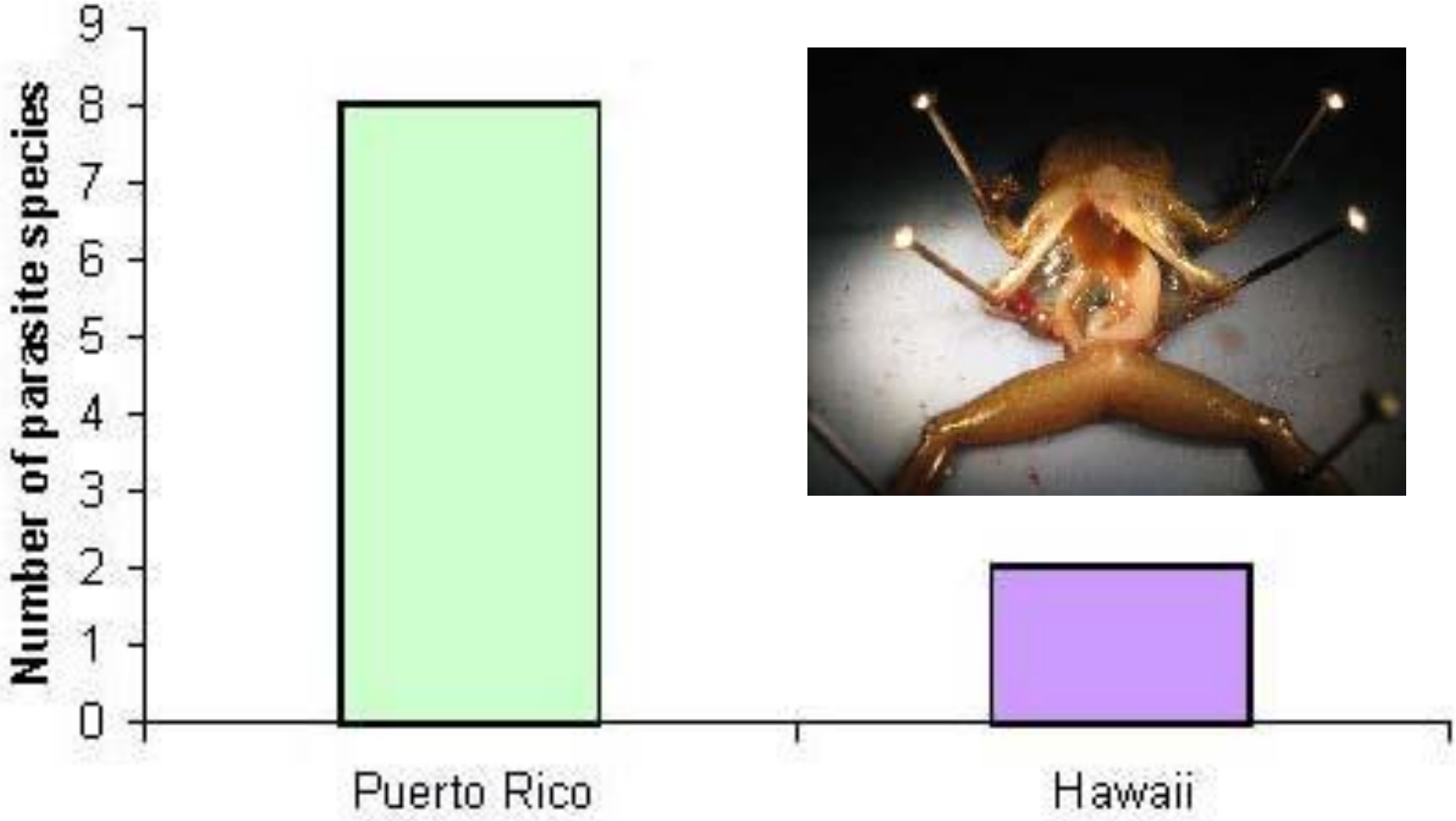
* ¾ -1 in. diam. PVC provides retreat and nesting site.
* Place trap on tree trunks 2-3 ft. above the ground where frogs are calling.
* Check traps for frogs & eggs every 2 wks.
* Trap efficiency is 21-37% .

¾ in. PVC with eggs & male

100 traps in 20 x 20m plot in 18 months:
> 5044 eggs &
770 frogs removed.

Internal Parasites of the Coqui Frog

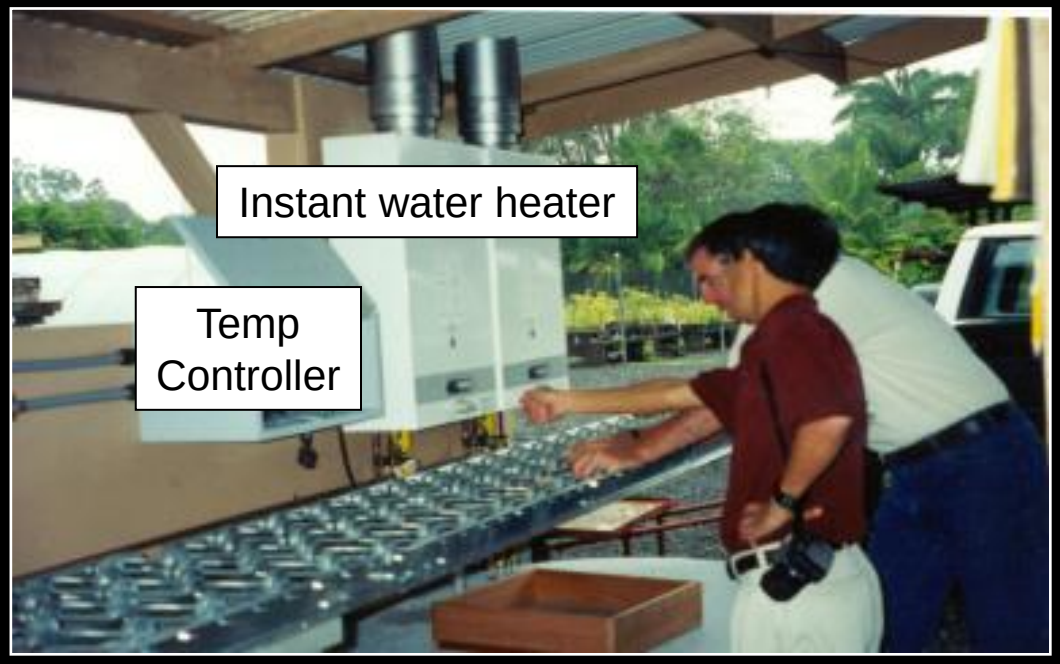
Parasite Species Richness: Puerto Rico > Hawaii



Biological Control against Coqui Frogs

* The lung nematode, *Rhabdias,* that infects coqui frogs in PR but not HI was tested against coqui in Hawaii.

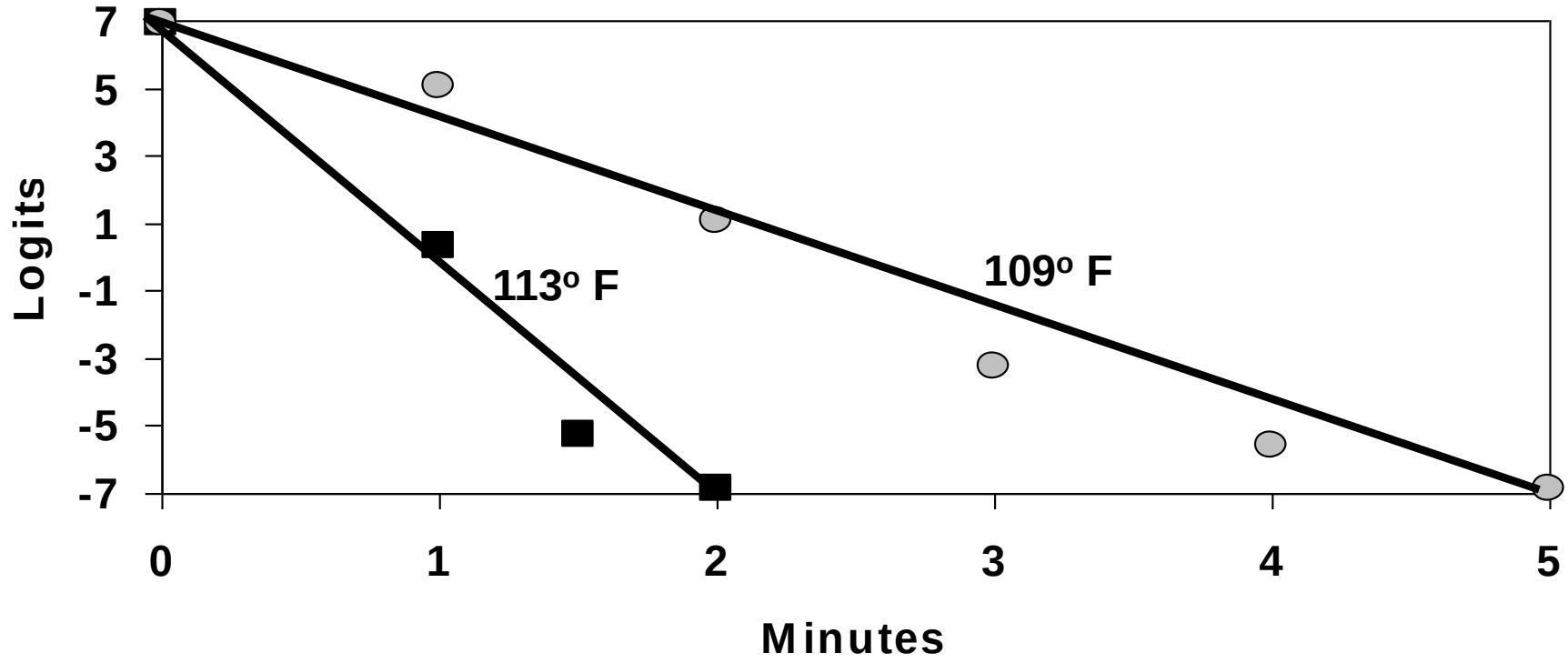
* Test results suggest *Rhabdias* did not strongly affect survival, growth, or endurance of coqui frogs.



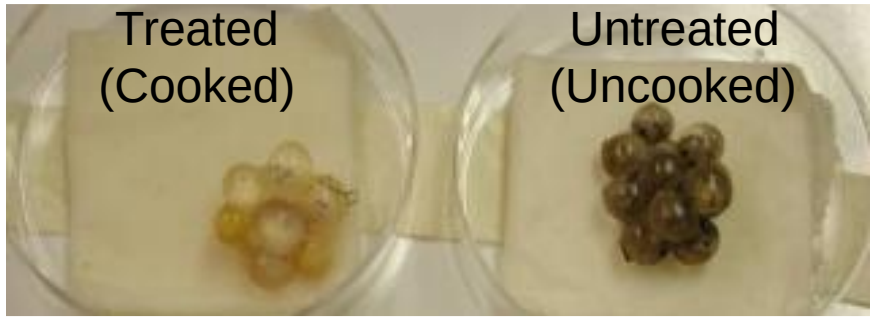
Hot Water Shower for plants to prevent spread of coqui frogs

* Treated at 113F for 3 min kill frogs/eggs.
* Plants are not detrimentally affected.
* Plants are treated immediately prior to transporting or shipping.
* Hot-water shower system installed at the Division of Forestry & Wildlife,for forest seedlings.

Coqui Frog Eggs Dipped in Hot Water



■ 45C; Y=6.89947-7.23609X ○ 43C; Y=7.05176-3.00833X



Temp & Time Required to Eliminate Egg Hatch

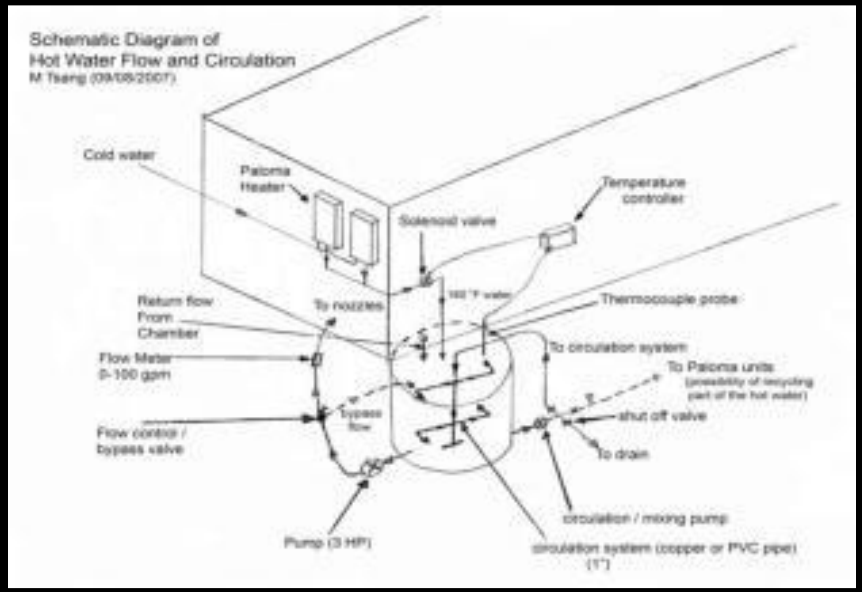
113º F = 2 min

109º F = 5 min

HOT SHOWER QUARANTINE TREATMENT

A Matson 24 ft refrigerated container modified into a hot shower chamber

Dead frogs, geckos, slugs at
113 F for 5 min



The Reality

* Coqui frogs populations in Hawaii will continue to increase with unlimited supply of food and nesting sites, and no predator or disease to keep in check.
* No known effective biological control agent (predator, parasite, disease).
* No known effective chemical control strategy.
* Presently, there is no further research funding for coqui frog control.
* The coqui frog is a good lesson in invasive species management. Once established, eradication is impossible.

Erythrina Gall Wasp

Quadrastichus erythrinae Kim

(Hymenoptera: Eulophidae)

Spread was like a wild fire

- **First described in 2004 causing severe damage in Taiwan and Singapore.**
- **First found on Oahu in April 2005.**
- **Found in Big Island, Kauai, and Maui in July 2005.**
- **Most of windbreak erythrina and Indian coral trees were killed.**

Heu / Nagamine

Erythrina Gall Wasp

Major Control Strategies

Short Term:

Chemical Control

- Drenches and Injections

Long Term:

Classical Biological Control

- Natural enemies from Africa

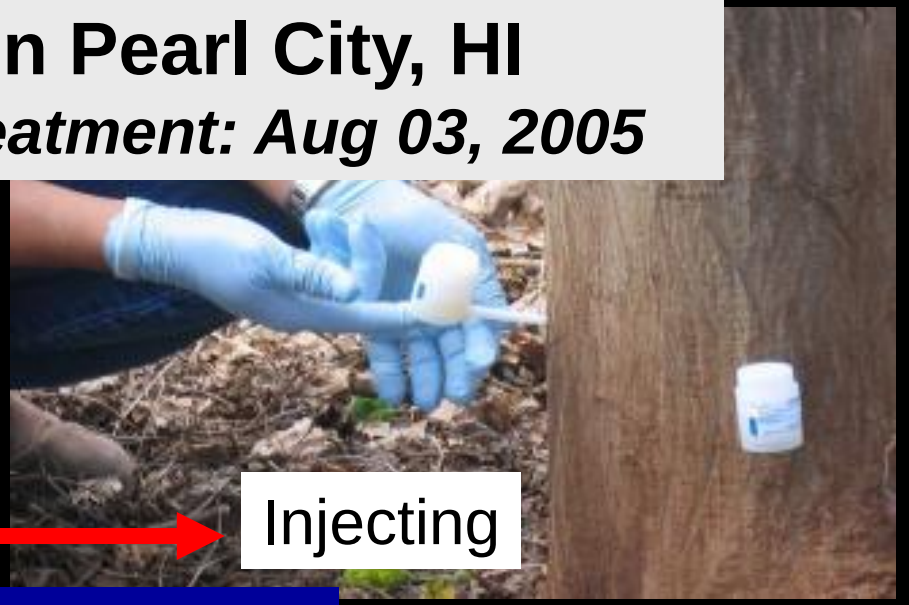
Cultural Control

- Tolerant cultivars

First Study Site in Pearl City, HI

Injection and Drench Treatment: Aug 03, 2005

Drilling



Injecting

Applying Treatments

Trenching

Drenching

Injection Systems Evaluated


Sidewinder Tree Injector


Mauget Tree Injectors

12 Weeks After Treatment

Treated trees showing concentration effect with different injection system and imidacloprid formulations

Erythrina Gall Wasp, A Successful Biological Control Project in Hawaii

On O'ahu alone, nearly 2,000 trees died at city parks and golf courses

* First described in 2004 causing severe damage in Taiwan and Singapore.
* First found on Oahu in April 2005.
* Found in Big Island, Kauai, and Maui in July 2005.

GALL WASP PREDATOR WINNING BATTLE

The state's battle with the gall wasp is making progress. A year after the introduction of *Eurytoma erythrinae*, a parasitic insect from Tanzania, the native wiliwili trees in Koko Crater Botanical Garden are making a comeback.

TIMELINE

April 2005 – Gall wasps discovered on O'ahu, then spread rapidly throughout state.

December 2005 – Exploratory entomologist Mohsen Ramadan travels to Tanzania in east Africa to track natural enemy of wasp, brings *eurytoma erythrinae* back to Isles.

2006-08 – Research, testing, monitoring and permitting to ensure that the new import would not attack any other insect or plants.

November 2008 – First of the tiny gall wasp predators released in stand of wiliwili trees in Honolulu.

2009 – Native wiliwili trees that were bare of leaves start recovering, sprouting full, green canopies.

M. Tremblay, UH-CTAHR photo

THE BAD BUG

Erythrina gall wasp

Size: **Female: 1.5 mm**
Male: 1.0 mm

(about the size of a grain of salt)

THE GOOD BUG

Eurytoma erythrinae

Size: **Female: 4.0 mm**
Male: 2.5 mm

(about the size of a black sesame seed)

A Successful Classical Biological Control

Hawai'i Dept. of Agriculture photos

BEFORE INTRODUCTION: This photo taken on Dec. 3, 2008, shows a wiliwili tree infested by gall wasps. Most of the tree's leaves are gone.

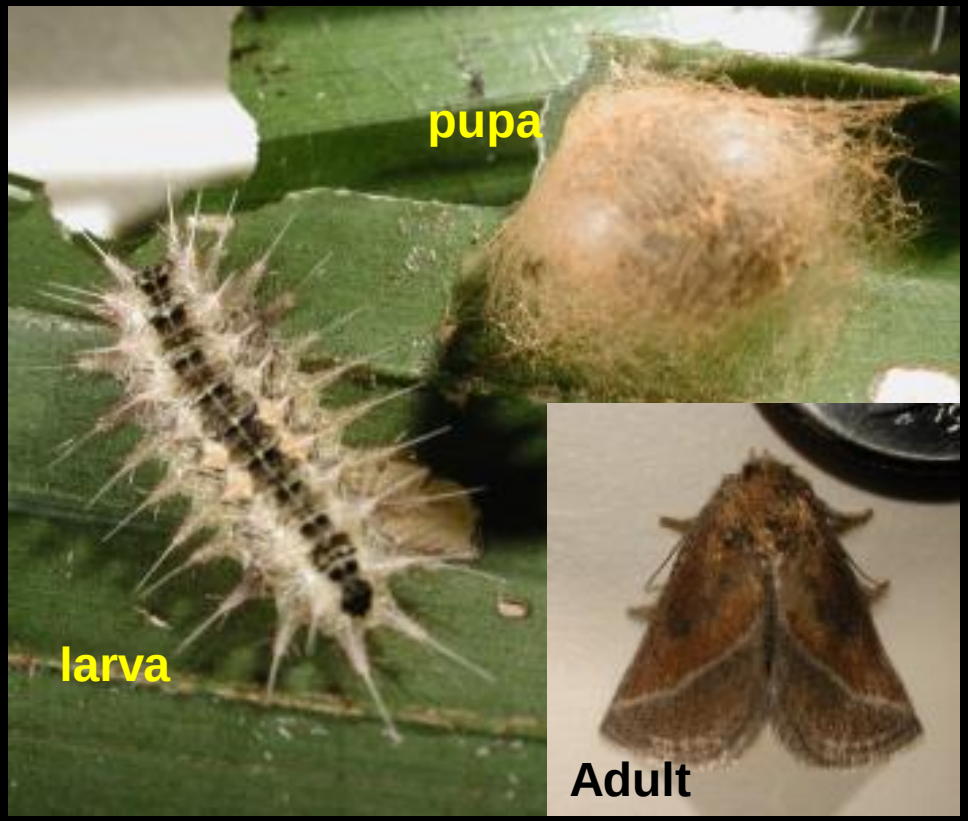
1 YEAR AFTER INTRODUCTION: A year later, after introducing *eurytoma erythrinae*, a natural gall wasp predator, the leaves are back.

Nettle caterpillar (NC), *Darna pallivitta*

Lepidoptera: Limacodidae

* First discovered on rhapis palm in Hilo, HI in 2001 by nursery workers who were stung by the caterpillar's spines.

* Big Island is heavily infested; has spread to all the major Hawaiian Islands.
* Also found in Taiwan, China, Thailand, Malaysia, Indonesia & Java.
* Probably arrived from Taiwan on a shipment of rhapis palm seedlings in the pupal stage.
* In addition to feeding damage, larvae inflict a painful sting when their spines that release venom (mixture of histamines) upon contact with the skin.
* Heavy feeding damage observed on: palms (rhapis, fishtail, phoenix, areca, coconut), Dracaena, ti-leaf..



Initial infestation of the nettle caterpillar on rhapis palms at a farm in Hilo, Hawaii, 10/2001

* Application of Sevin (carbaryl) with hydraulic sprayer by grower.
* Decathlon (cyfluthrin), Dursban (chlorpyrifos) also used against caterpillars in a rotation.
* Dibrom (naled) used against the adults.
* Repeated sprays every two weeks for two months, but efforts failed..

NC infestation on mondo grass at a neighboring nursery

Long Term Control Strategy

Classical Biological Control

* An effective natural enemy was discovered in Taiwan and imported to Hawaii.
* Approval for release of this parasitic wasp by Hawaii Board of Ag and USDA was achieved in 2010.
* Parasitic wasp is providing a significant mortality factor for the nettle caterpillar in Hawaii.

Adult and pupae of a eulophid wasp, *Aroplectrus dimerus*, that emerged from a nettle caterpillar.

Adult wasp on caterpillar

Doing nothing is more cost effective

Successful Fortuitous Biological Control: Giant Whitefly May 2002

* In March 2003 (10 months later), a pteromalid wasp, *Idioporus affinis* was found parasitizing giant whitefly.

* This wasp was introduced into California from Mexico for biological control of giant whitefly.

* This wasp apparently arrived fortuitously in Hawaii along with giant whitefly.

* Subsequent surveys indicate that the wasp is widespread on all islands and providing excellent control of the whitefly. (Heu et al. 2004)

“Is doing something better than doing nothing?”

Giant Whitefly

Aleurodicus dugesii

May 2002 –

* First discovered in HI heavily infesting hibiscus, fiddlewood, plumeria.

Merit drench – (Best Guess)

* Applied to infested fiddlewood trees by City in Chinatown

* Not effective; improper application at base of trunk and not canopy drip line to feeder roots.

Slugs intercepted in Hawaii on Christmas Trees from Oregon, Nov. 2011

Photos by L. Iseke, HDOA

hot shower chamber

Douglas Fir trees 14 days after hot shower treatment at 118 F for 8 min. No significant heat damage observed.

Approx. 5,000 trees were treated with hot shower at 118 F to kill slugs

Reality

- The invasive species crisis will only intensify in Hawaii with increase in global trade and imports.
- The worst invasive species are not insects, but vertebrates (e.g., brown tree snake, frogs, birds, lizards).
- Classical biological control has been very effective.
- Fortuitous biological control has also been effective.
- Our programs (county, state, federal and university) are not effectively addressing the invasive species crisis.
- We are only reacting to the invasive species crisis.
- Hawaii has no proactive program to address invasive spp.

Python snakes found in Hilo, Hawaii July 14, 2011

Keevin Minami, Land Vertebrate Specialist, HDOA, Plant Quarantine

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