MANAGEMENT OF THREE NEW INVASIVE SPECIES IN HAWAII:

CYCAD SCALE *Aulacaspis yasumatsui* Takagi (Homoptera: Diaspididae), NETTLE CATERPILLAR *Darna pallivitta* Moore (Lepidoptera: Limacodidae), and COQUI FROG *Eleutherodactylus coqui* (Anura: Leptodactylidae)

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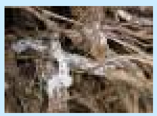
CYCAD SCALE

DISTRIBUTION

- ***Aulacaspis yasumatsui*** **was discovered in Florida in 1996, threatening several endangered cycad species in botanical gardens. It is native to Thailand where natural enemies keep them in check. In Hawaii, *A. yasumatsui* was first found on the island of Oahu in 1998 on sago palms, *Cycas revoluta*, and spread to the Big Island in 2000, Kaua'i in 2003, and Maui in 2004.**

PLANT DAMAGE

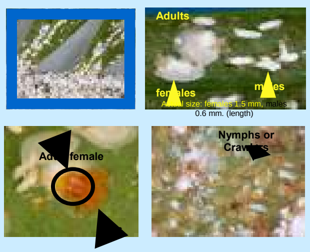
- ***A. yasumatsui*** **causes feeding damage to leaves, stems, trunk and roots, sucking out plant sap. Over several months, leaves become chlorotic, eventually turn brown, then die. New leaf flushes may be stunted (far left).**



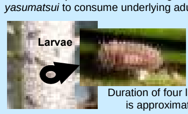
Cycad scale infestations on trunk, stems (left) and roots (right) can be a source of reinfestation when new leaves emerge on sago palms.

LIFE CYCLE

- **The average life cycle of the cycad scale is approximately 35 d from egg to adult (average longevity 75 d).**
- **Female adults are covered with a hard, white, waxy, oval-shaped armor. The male pre-adult has an elongated, striated, shell-like covering. The adult male has wings and is capable of flying.**
- **Females lay approximately 100 eggs under the armor. Eggs hatch in 7 to 14 d into nymphs, which are light, buoyant, and easily dispersed by wind prior to settling to feed.**
- **Nymphs develop into mature scales in approximately 30 d.**

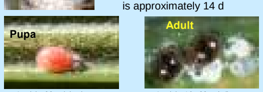


Adult *R. lophanthae* chew through the armor of *A. yasumatsui* to consume underlying adult scale & eggs.



Actual size: 3.2 to 4.8 mm in length

Duration of four larval stages is approximately 14 d



Actual size: 3.2 mm in length

Actual size: 1.6 to 2.3 mm in diameter

BIOLOGICAL CONTROL

- A tiny black lady beetle, *Rhyzobius lophanthae,* is HIGHLY EFFECTIVE in controlling the cycad scale and should be the primary control strategy.
- *R. lophanthae* was introduced to Hawaii in 1894 for biological control of other armored scales.
- Recent surveys on the Big Island, O'ahu, Maui and Kaua'i indicate that the lady beetle is established and can effectively control the cycad scale.
- Male and female adult beetles consume more than 400 and 800 scales, respectively.
- The life cycle of *R. lophanthae* from egg to egg-laying adult ranges from 24 to 32 d, shortening as temperature increases. Average longevity is 120 d.
- A single female beetle can lay more than 600 eggs.

EFFECTS OF PESTICIDES ON *R. LOPHANTHAE*

- Control of *A. yasumatsui* with chemical insecticides is not recommended because the adult female scale is protected by its armor. If sprays must be used, horticultural oils (e.g., Ultrafine, Volck) are preferable because they pose less threat to *R. lophanthae* establishment.
  - In Florida, horticultural oils were most effective against the tiny scale crawlers when applied with good coverage and with 4 repeated applications at 10-14 d intervals.
- Low to moderate scale infestations may be controlled with the new insect growth regulators (e.g., Distance (pyriproxyfen) or Talus (buprofezin).
- Broad spectrum insecticides (Malathion, Diazinon, pyrethroids) are highly toxic to the lady beetles.
- Among the systemic insecticides, Safari (dinotefuran) is labeled for use on cycad scales and should be effective.

NETTLE CATERPILLAR

DISTRIBUTION

- **The nettle caterpillar was first found in Hawai'i in 2001 by nursery workers in Hilo, HI who were stung by its spines while processing rhapis palms; probably arrived from Taiwan but is also found in China, Thailand, Malaysia, and Indonesia.**
- ***D. pallivitta*** **is of major concern due to its painful sting, voracious appetite, lengthy larval feeding stage (2 months), high fecundity (480 eggs per female), and wide host range. Many of its host plant species are of high economic value and are common in residential & commercial landscaping and in natural habitats.**

FEEDING DAMAGE

Smaller larvae feed only on the leaf surface, creating a "window pane" effect.

Larger larvae eat the entire leaf, often leaving only the hard midribs behind. A heavy infestation can defoliate a potted plant in just a few days.

LIFE CYCLE

(egg to adult varies from 72 - 99 d

EGG

Laid in clusters, lines, or singly

Developing larvae visible within flattened eggs with gel-like chorion

(4 - 7 d)

FIRST INSTAR LARVA

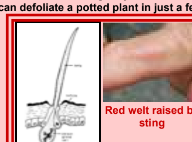
(45 - 72 d)

LARVAL STAGE VARIES FROM 8 - 11 INSTARS

PREPUPA & PUPA

(17 - 21 d)

ADULT



Red welt raised by sting

The caterpillar's stinging scoli release on contact a mixture of histamines produced by a poison gland (left), causing a burning and itching sensation to the skin (right). The spine also has a mechanical effect similar to fiberglass. Irritation to the eyes can be acute.

CULTURAL CONTROL

- **Control weeds and landscaping to reduce food available to nettle caterpillars.**
- **Do not relocate any known host plants from an infested area into your garden or landscaping area to avoid transporting eggs that are difficult to detect.**

ADULT MOTH ACTIVITY

- **Due to adult moths' instictive attraction to light, minimize outdoor lighting at night.**
- **Females most active 40-70 min after sunset.**
- **Males most active from 2300-0600 h.**

PHEROMONE IDENTIFIED

- **Components of *D. pallivitta* sex pheromone were identified using gas chromatography and electroantennogram detection by USDA ARS in collaboration with HDOA, & UH-CTAHR, and when tested as bait in lure traps, male moths were effectively attracted (below, right).**
- **Use of a synthetic pheromone to disrupt mating may be more effective than lure traps in controlling *D. pallivitta* populations.**

BIOLOGICAL CONTROL

- **A locally-established trichogrammatid wasp was observed ovipositing into *D. pallivitta* eggs but has had limited effect on the Big Island.**
- **In collaboration with HDOA, researchers in Taiwan observed the larvae of *Aroplectrus dimerus* feeding and developing on *D. pallivitta*, killing its host (near right).**
- **In 2004, a cytoplasmic polyhedrosis virus (CPV) was discovered infecting larvae in Hawai`i and may potentially control heavy infestations of nettle caterpillar.**

Aroplectrus dimerus

Sample capture using pheromone bait

CHEMICAL CONTROL OF *Darna pallivitta* LARVAE

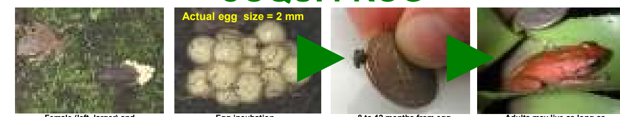
(repeat sprays every two weeks)

Brand Name	Common Name / Class	Moribund Days* (>95% mortality)
Decathlon	cyfluthrin / pyrethroid	3
Dursban	chlorpyrifos / organophosphate	3
Sevin	carbaryl / carbamate	14
Conserve	spinosad / spinosyns	14
Dipel	*Bacillus thuringiensis* / microbial	14

*Moribund caterpillars stopped feeding but brushing against spines will continue to cause stings.

This research has been possible through funding by a special USDA, CSREES Tropical & Subtropical Agriculture Research (T-STAR) grant 2005-34135-16410, *"Management Strategies for an Invasive Species in Hawaii: the Nettle Caterpillar".*

COQUI FROG



Female (left, larger) and male (right, guarding eggs)

Egg incubation 14 to 17 days

8 to 12 months from egg to egg-laying adult

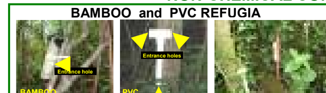
Adults may live as long as 4 - 6 years

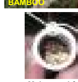
- **Males guard eggs to prevent desiccation and predation until hatching**
- **Egg clutch (cluster) size ranges from 34 to 75 eggs**
- **Clutches per year: 4 - 6 in native Puerto Rico; 24 - 28 in Hawaii under lab conditions**
- **Coqui frogs are entirely terrestrial, direct developers with no tadpole stage**

- **The coqui frog arrived from Puerto Rico into Hawaii in 1988.**
- **Intra-island spread of coqui frogs is associated with movement of plants, vehicles, building materials, and equipment from infested areas into residential, resort, commercial and natural landscapes.**
- **The coqui frog and the greenhouse frog, *E. planirostris* (Cope), threaten diversified agriculture, native eco-systems and the quality of human life (noise, possible food source for snakes), and are inter-island, potential national and international quarantine pests on plant materials from >345 infested sites in the state.**

NON-CHEMICAL CONTROL METHODS

BAMBOO and PVC REFUGIA





Male coqui frog guarding eggs inside PVC pipe

- **Traps are staked 2-3 ft above the ground in infested areas (above, far right), and checked and emptied every 2 wk.**
- **Coqui frogs show a preference to PVC over bamboo.**
- **Trap efficiency in tests at Lava Tree State park ranged from 22-40%.**

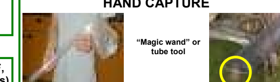
CULTURAL CONTROL

Remove non-native plants

Yard with buffer zone

Modify habitat to be less appealing to frogs. Remove under-story to reduce water retention and nesting sites; replant with small-leafed native plants

HAND CAPTURE



"Magic wand" or tube tool

A length of plastic tubing (fluorescent light bulb shield) can be used to capture frogs – place open end over frog and it will instinctively hop up into the tube. *From: HI Dept. of Agriculture, N. Matayoshi*

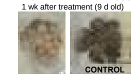
VAPOR HEAT CHAMBER FOR POTTED PLANTS

Diamond Head Papaya Co., Kea`au, HI
Capacity: 20 pallets; Ht: 1.8 m

- **2-day old eggs were treated at 113 °F, >90% r.h. for 10 min (20 min for adults).**
- **2 weeks after treatment, the control eggs hatched; the treated eggs did not.**

VAPOR HEAT TREATED EGGS

1 wk after treatment (9 d old)



COLD TREATMENT

Subjecting eggs and adult frogs to 2.2-3.3 °C for 6 hours prevented hatching and provided 100% mortality.

HOT WATER SHOWER SYSTEM FOR POTTED PLANTS

(45 °C for 5 min to 46 °C for 3 min - for eggs, adults & froglets)

EXTERIOR

- **Polyvinyl coated aluminum-framed storage container**
- **Digitally controlled tankless propane heater**
- **Nozzles deliver 0.51 gpm (1.9 lpm)**
- **Water recycled by pump through screen filter and ultraviolet water purifier**
- **Plant damage is minimal (open flower blooms and sensitive plants (certain orchids, impatiens, petunia))**

Designed by Charles Nelson, UH CTAHR & Bill Durston, Leilani Nursery

INTERIOR

BIOLOGICAL CONTROL (PREDATORS) IN PUERTO RICO

rats, cats, mongoose, birds (egrets, chickens, geese), large spiders, including tarantulas, scorpions, larger reptiles/amphibians

**observed feeding on coqui frogs in Hawai`i*

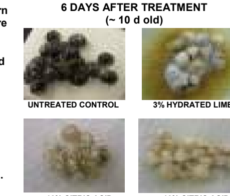
CHEMICAL CONTROL

Both hydrated lime and citric acid are available to control coqui and greenhouse frogs in Hawai'i. Both chemicals are corrosive and burn the skin of the frog, interfering with its ability to respire, and require direct contact with the frog or eggs, having no residual effect.

HYDRATED LIME: Hydrated lime (calcium hydroxide) is approved and labeled by US EPA to treat outdoor ornamental plants in nurseries and residential areas, parks, hotels and resorts, and forest habitats. Mortality among eggs treated with 3% hydrated lime suspension at 4 to 10 d old was 100%. Hydrated lime applied as a foliar or drench spray is not generally phytotoxic but will leave a white residue and raise soil pH.

CITRIC ACID: Citric acid, a common food additive, is considered a minimum risk pesticide by US EPA, and is, therefore, not regulated. Either no rinsing or rinsing one hour after application of 16% citric acid greatly reduced hatch rate (97% effective) compared to the untreated controls. Phytotoxicity studies using 25% citric acid conducted on a variety of ornamental plants indicated that palms and dracaena varieties were the most tolerant to citric acid.

COQUI FROG EGG VIABILITY 6 DAYS AFTER TREATMENT (~ 10 d old)



UNTREATED CONTROL

3% HYDRATED LIME

16% CITRIC ACID NO RINSING

16% CITRIC ACID RINSING 1 HR AFTER TREATMENT

For more ... in Hawai'i" This research is being done as part of the Tropical/Subtropical Agricultural Research (T-STAR) Pacific Basin Special Research Grant 2003-34135-13982: "Management of a New Invasive Species in Hawai'i: The Coqui Frog"