

NOTE

Images in this `reveal.js` slide deck were extracted using
this ImageMagick command:

```
convert -density 150 -antialias BioinvasionOfGuamForests.pdf -
```

and inserted into an HTML template using a Python
script in a Jupyter notebook.

Details available at

https://github.com/aubreymoore/PDF_to_Reveal

Aubrey Moore, University of Guam

BIOLOGICAL INVASION OF FORESTS ON GUAM AND OTHER ISLANDS IN MICRONESIA

Aubrey Moore

Forestry Workshop on Invasive Insects
University of Guam, Feb. 11, 2020

Biological Invasion of Forests on Guam and Other Islands in Micronesia

Aubrey Moore

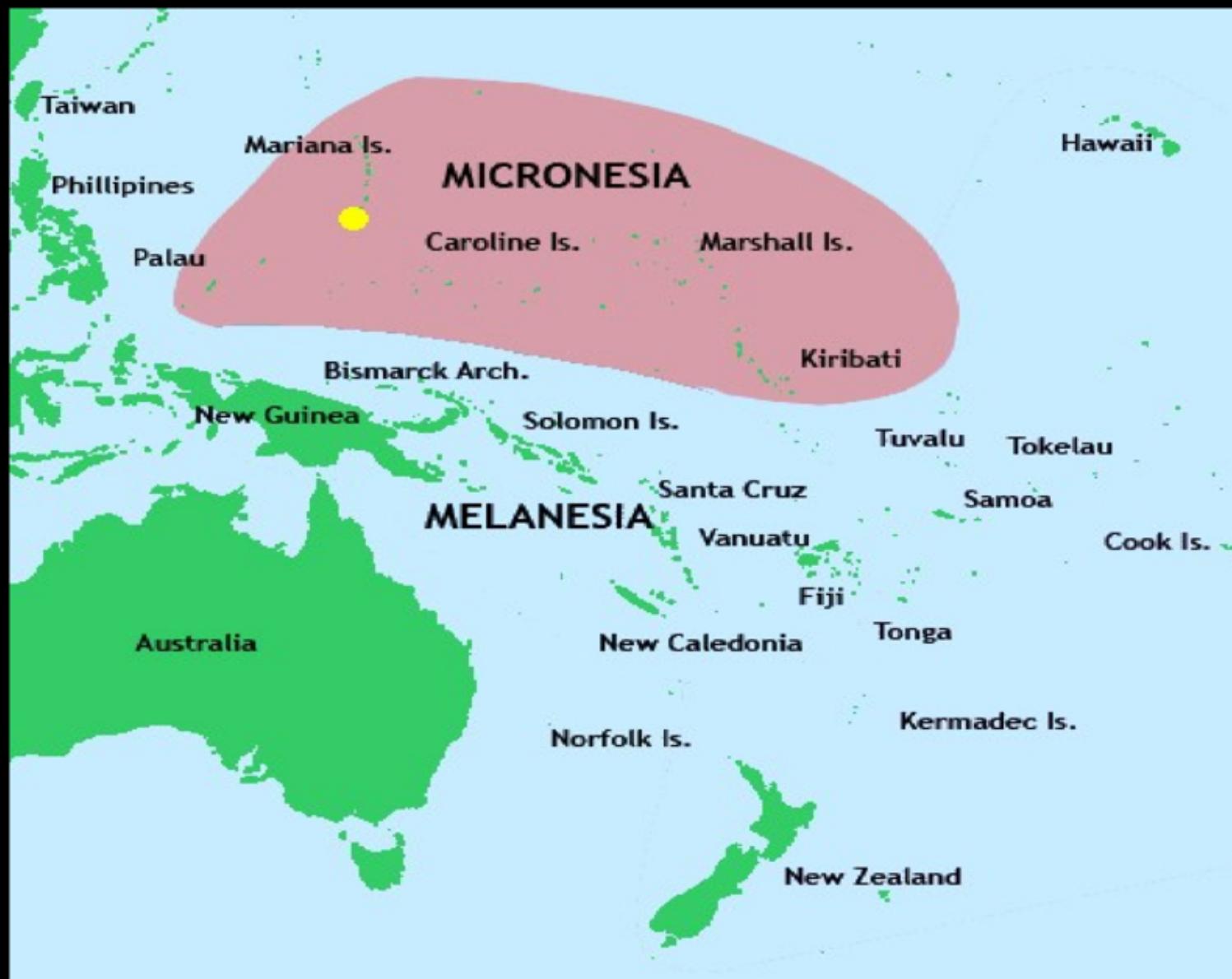
Cooperative Extension Service / Western Pacific Tropical
Research Center
College of Natural and Applied Sciences
University of Guam

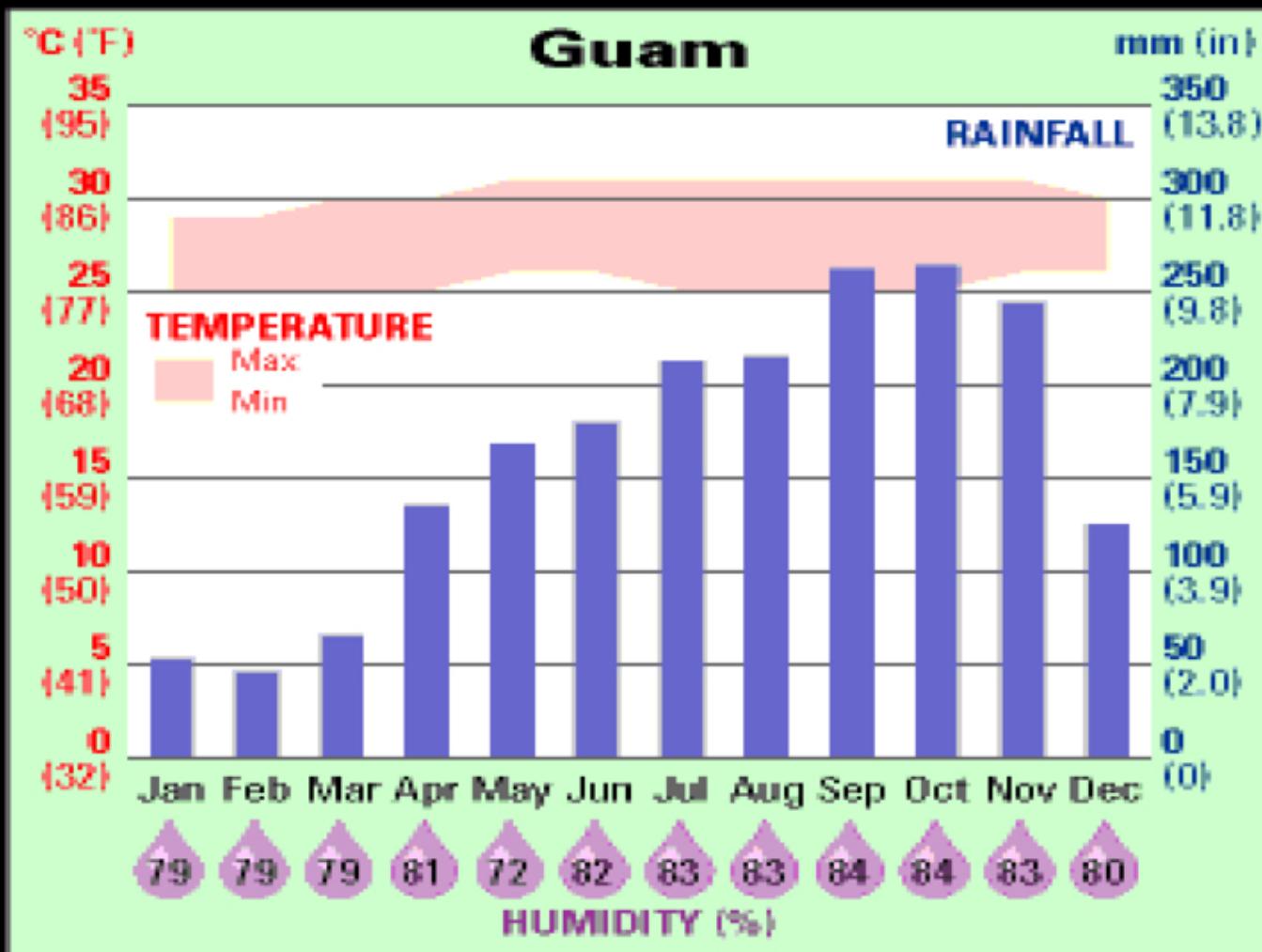
Native and Invasive Pest Issues of the Pacific Islands
Western Forest Insect Work Conference
Sacramento, CA
April 1, 2014

Outline

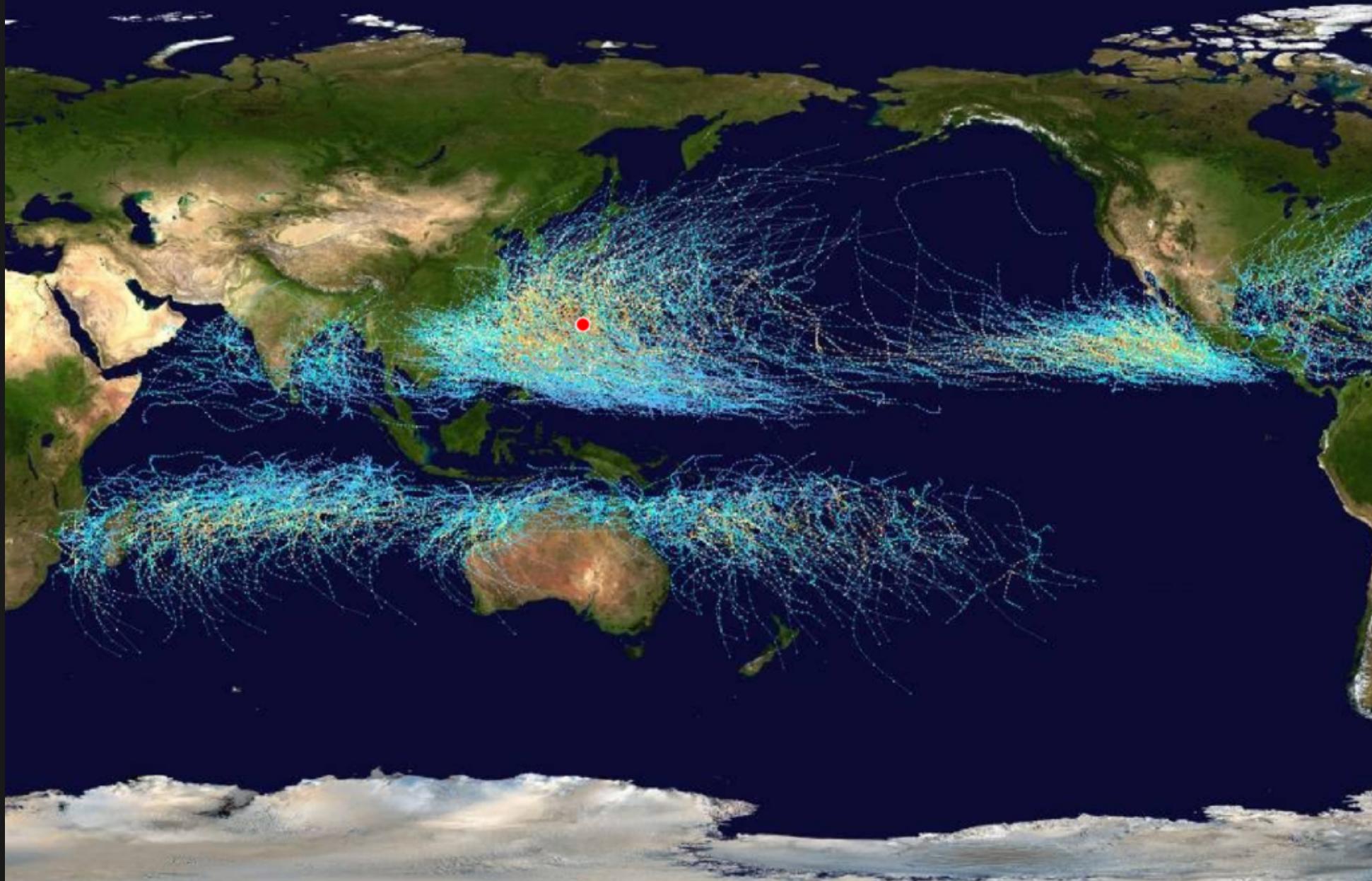
- Introduction to Guam and Micronesia
- Major Animal Invaders
 - Ungulates: deer, pigs, caribao
 - Brown treesnake
 - Asian Cycad Scale and Associates
 - Coconut Rhinoceros Beetle
 - Little Fire Ant
- Other Animal Invaders of Concern
 - Termites
 - Hemipterans
 - Bark beetles
 - Erythrina gall wasp
 - Casuarina gall wasp
 - Snails and slugs

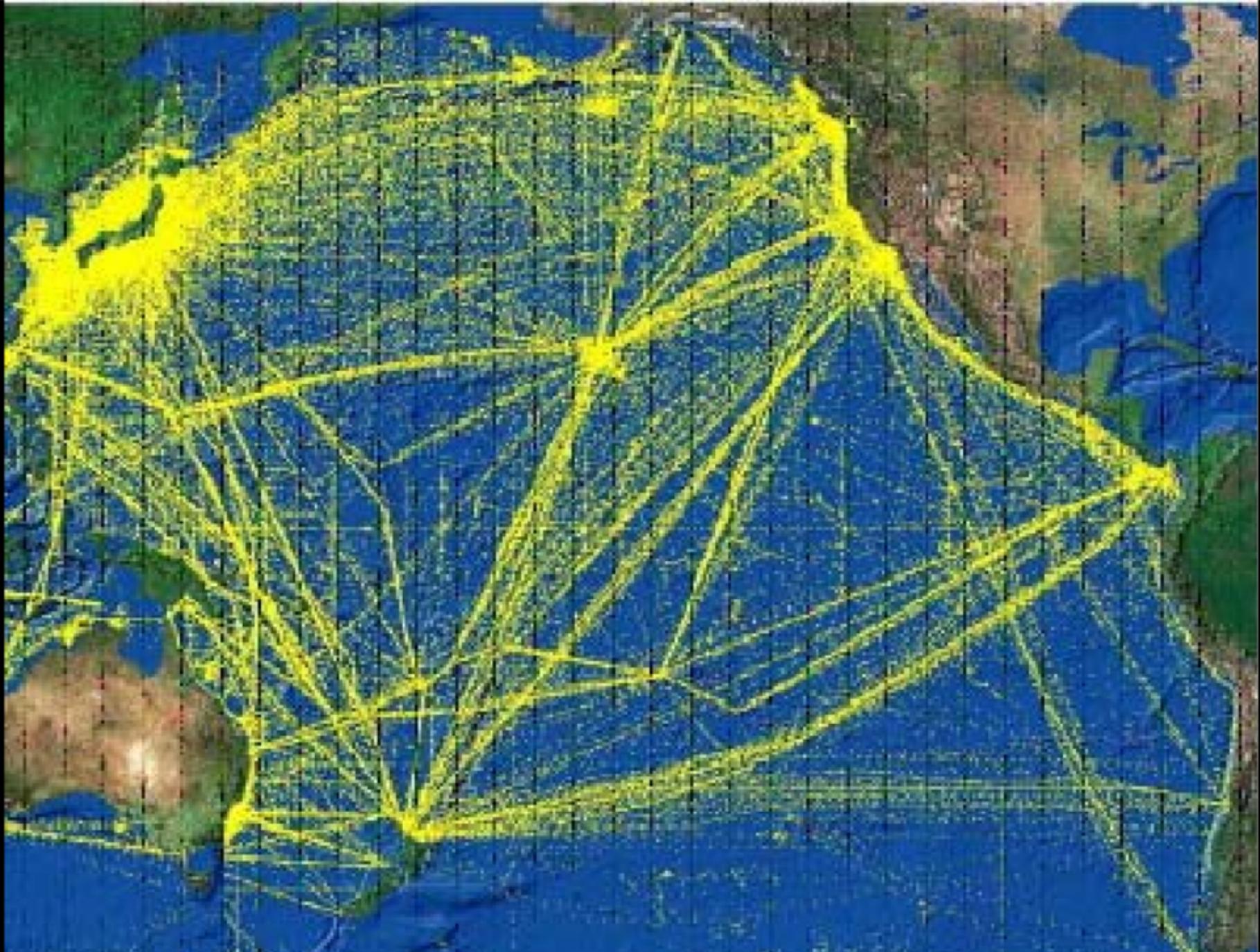
Where is Guam?



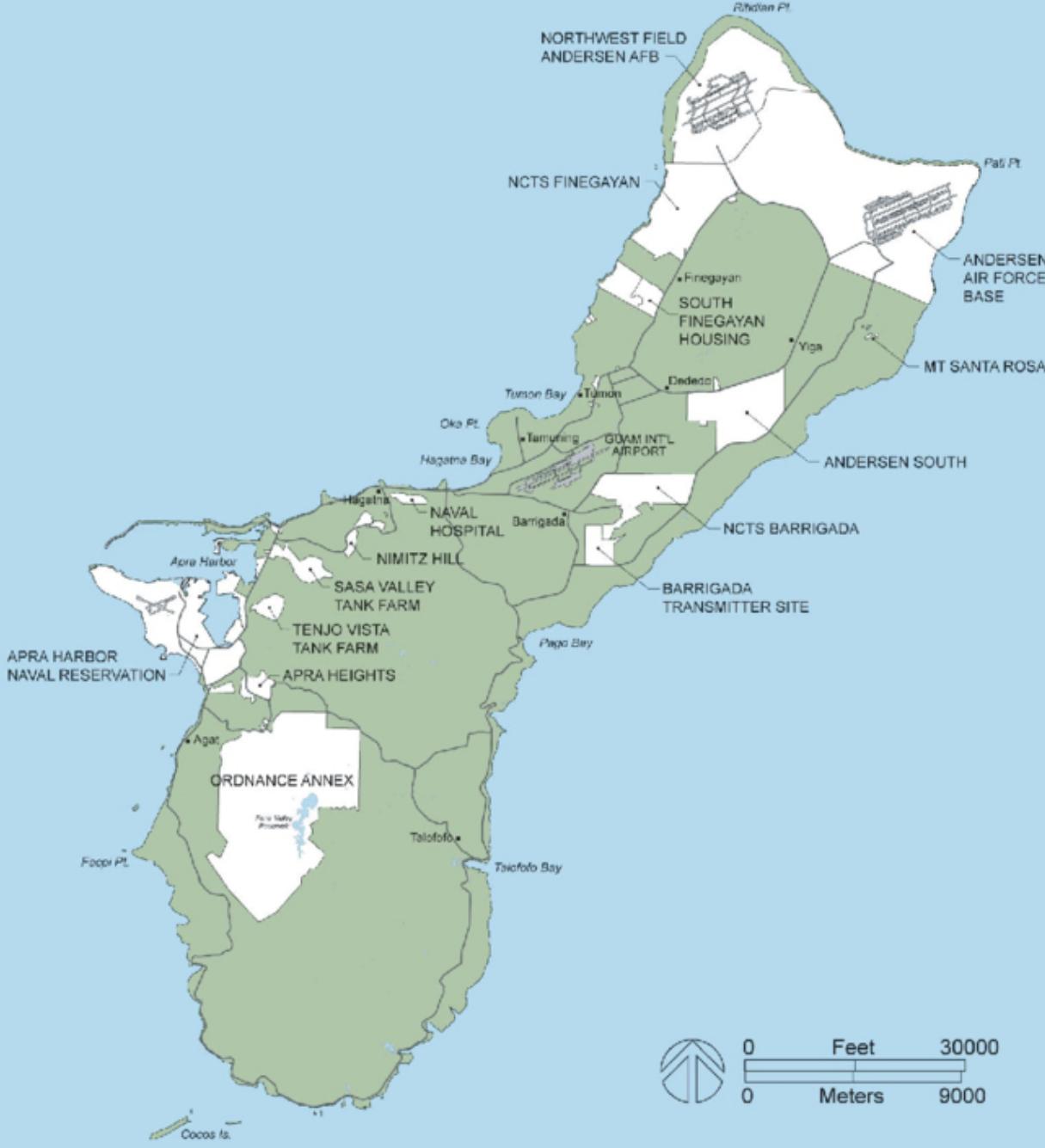


This map shows the tracks of all Tropical cyclones which formed worldwide from 1985 to 2005.





Air and sea traffic patterns in the Asia-Pacific region



Major Animal Invaders of Guam's Forests

- Ungulates: deer, pigs, caribao
- Brown treesnake
- Asian Cycad Scale and Associates
- Coconut Rhinoceros Beetle
- Little Fire Ant

Ungulates





Loss of native forest
Few young trees survive
intensive browsing

Before deer and pig fence
erected March 2004 (NW Field
AAFB)

22 months after deer and pigs
excluded January 2006







Major Animal Invaders of Guam's Forests

- Ungulates: deer, pigs, caribao
- Brown treesnake
- Asian Cycad Scale and Associates
- Coconut Rhinoceros Beetle
- Little Fire Ant

There are no native snakes in Guam, CNMI, FSM, Marshall Islands and Hawaii



- BTS arrived on Guam accidentally in late 1940's to early 1950's
- Nocturnal
- Tree dwelling
- Mildly venomous
- Avg. size = 4.5 ft.
- High snake densities (up to 45 per acre)





Effects of Brown treesnake on Guam's Forests

- Loss of ecosystem services provided by birds and other BTS prey:
 - Seed dispersal
 - Pollination
 - Insectivory

For more info see: <http://ecologyofbirdloss.blogspot.com>

Possible Example of Forest Damage Due to Bird Loss: Katydid egg scars on sapling leaders



Major Animal Invaders of Guam's Forests

- Ungulates: deer, pigs, caribao
- Brown treesnake
- Asian Cycad Scale and Associates
- Coconut Rhinoceros Beetle
- Little Fire Ant

Case Study: *Aulacaspis Cycad Scale*



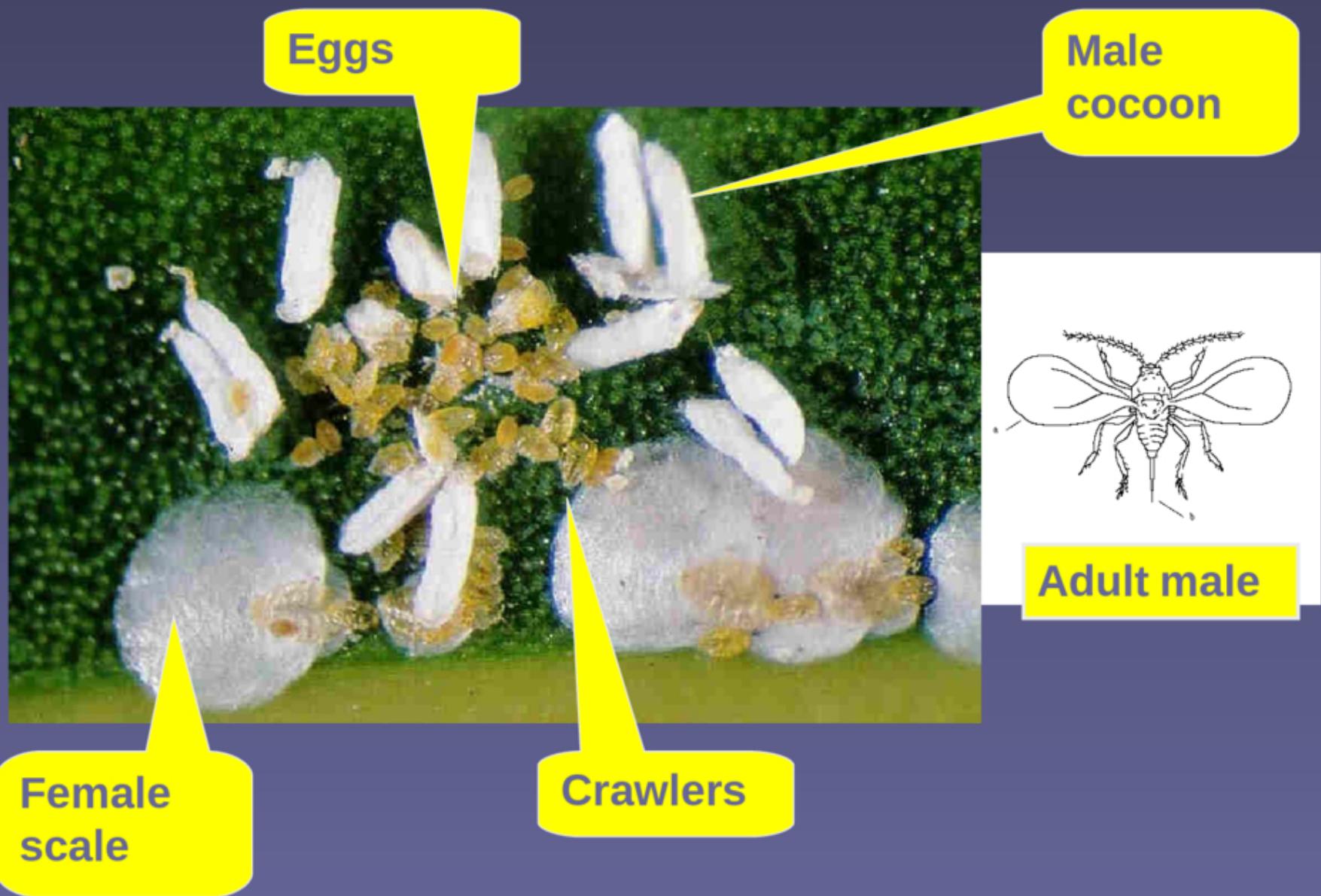
Case Study: *Aulacaspis Cycad Scale*



Case Study: *Aulacaspis Cycad Scale*



Scale Morphology & Life History

















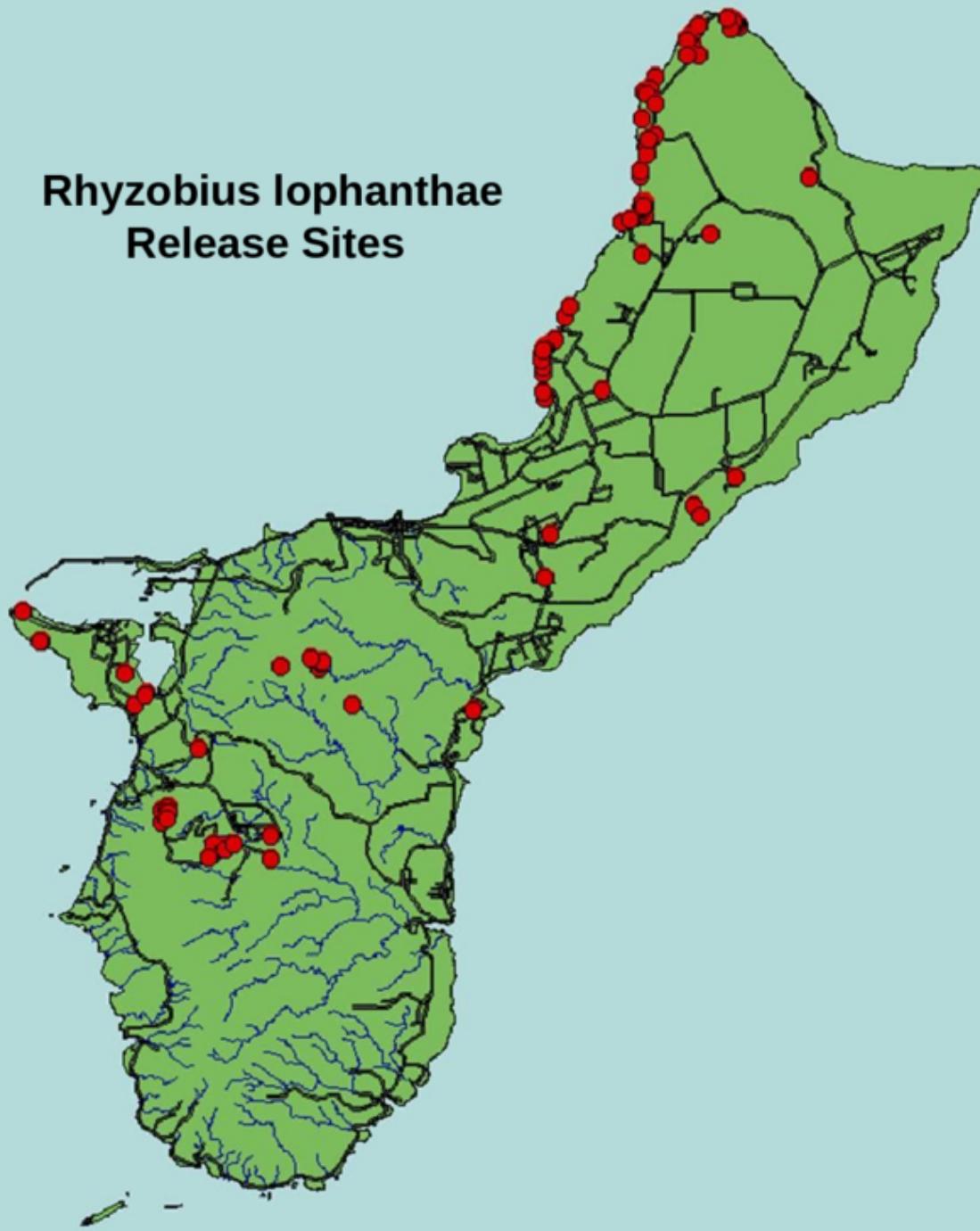








Rhyzobius lophanthae
Release Sites



Fadang plants flush at start of 2005 rainy season





Cycad Blue Butterfly

Chilades pandava

New cycad growth defoliated by *Chilades pandava* larvae



Chilades pandava larva on *Cycas micronesica* with attendant ant, *Aplopopolepis gracilipes*



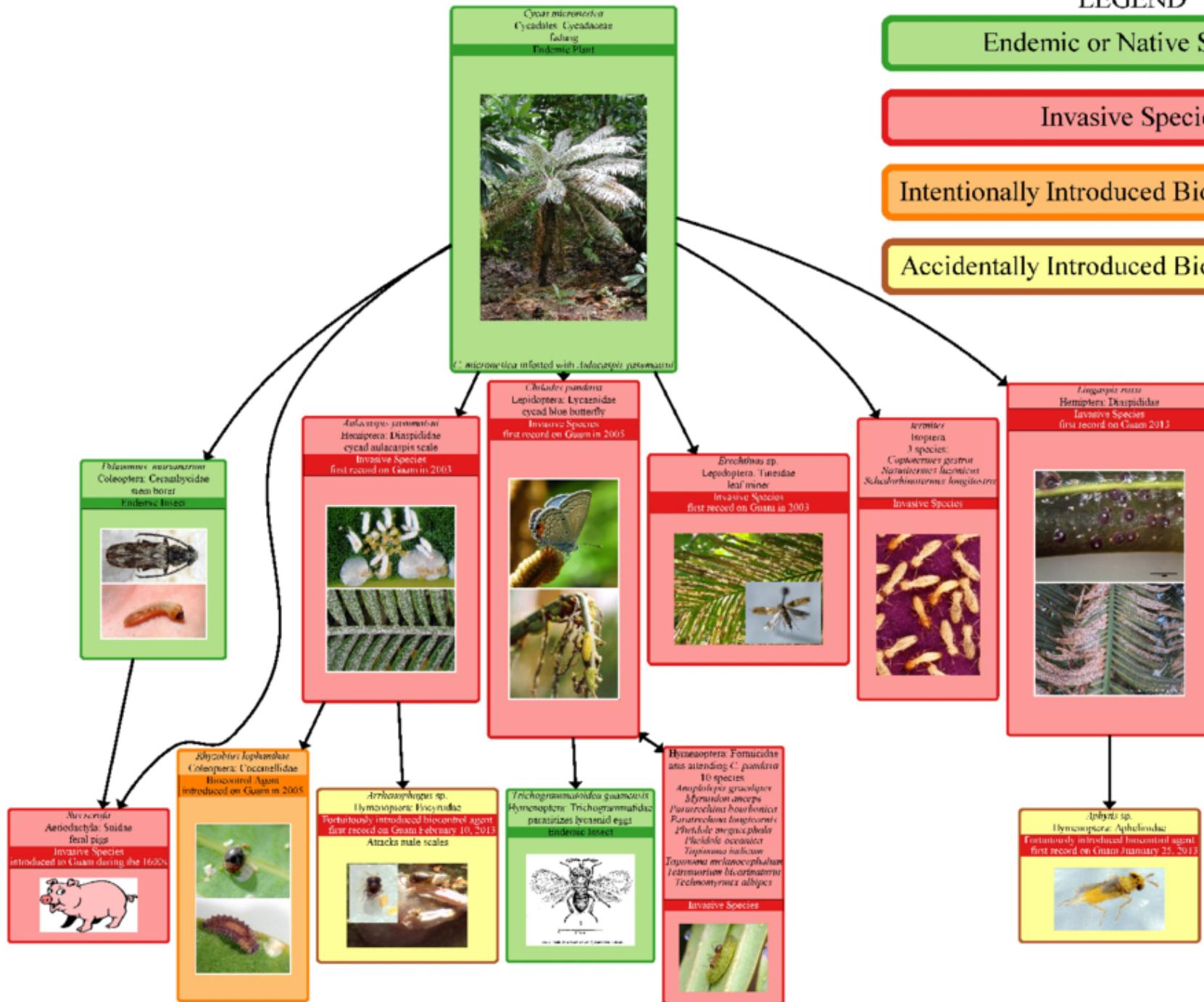
LEGEND

Endemic or Native Species

Invasive Species

Intentionally Introduced Biocontrol Agent

Accidentally Introduced Biocontrol Agent



Decline of *Cycas micronesica* Following Infestation by *Aulacaspis yasumatsui*

- First detected on ornamental plant in November 2003
- Escapes to wild cycads within 1 year
- Placed on IUCN Red List of Threatened Species in 2006
- Only 7% of plants have survived and no reproduction has been seen since 2005

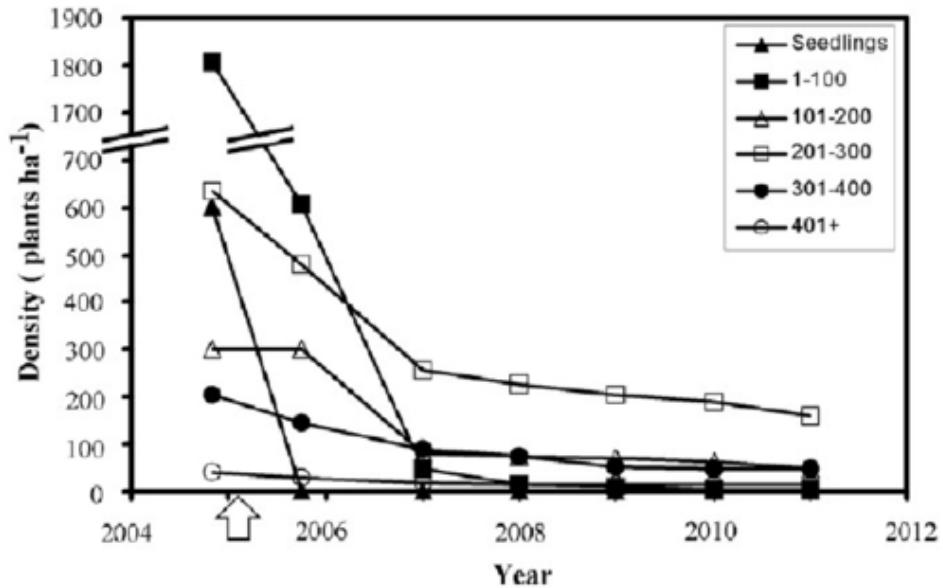


Figure 2. The influence of plant height size categories (cm) on survival of *Cycas micronesica* following the establishment of *Aulacaspis yasumatsui* in western Guam. The x-axis refers to January of each calendar year. Arrow on x-axis marks the initial infestation of *A. yasumatsui* in the study habitat.

Source: Marler, T.E. and J.H. Lawrence 2012. Demography of *Cycas micronesica* on Guam following introduction of the armoured scale *Aulacaspis yasumatsui*. *Journal of Tropical Ecology*, 28:233-242.

Major Animal Invaders of Guam's Forests

- Ungulates: deer, pigs, caribao
- Brown treesnake
- Asian Cycad Scale and Associates
- **Coconut Rhinoceros Beetle**
- Little Fire Ant

First Coconut Rhinoceros Beetle
Collected on Guam 11-Sep-2007
Tumon Bay



Oryctes rhinoceros Distribution



Coconut rhinoceros beetle invasion history

native range first detected in the 20th century first detected in the 21st century

open circle: population includes CRB-G biotype
filled circle: population is exclusively CRB-G biotype



map.geojson rendered with ❤ by GitHub



FELCO 2
SWISS MADE









Novel CRB Behavior on Guam: Arboreal Development

CRB extracted from the crowns
of 121 felled coconut palms



Eggs	99
L1	40
L2	72
L3	210
Pupae	25
Adult males	34
Adult females	30
Total	510
Mean per tree	4.21





ADULTS KILL TREES



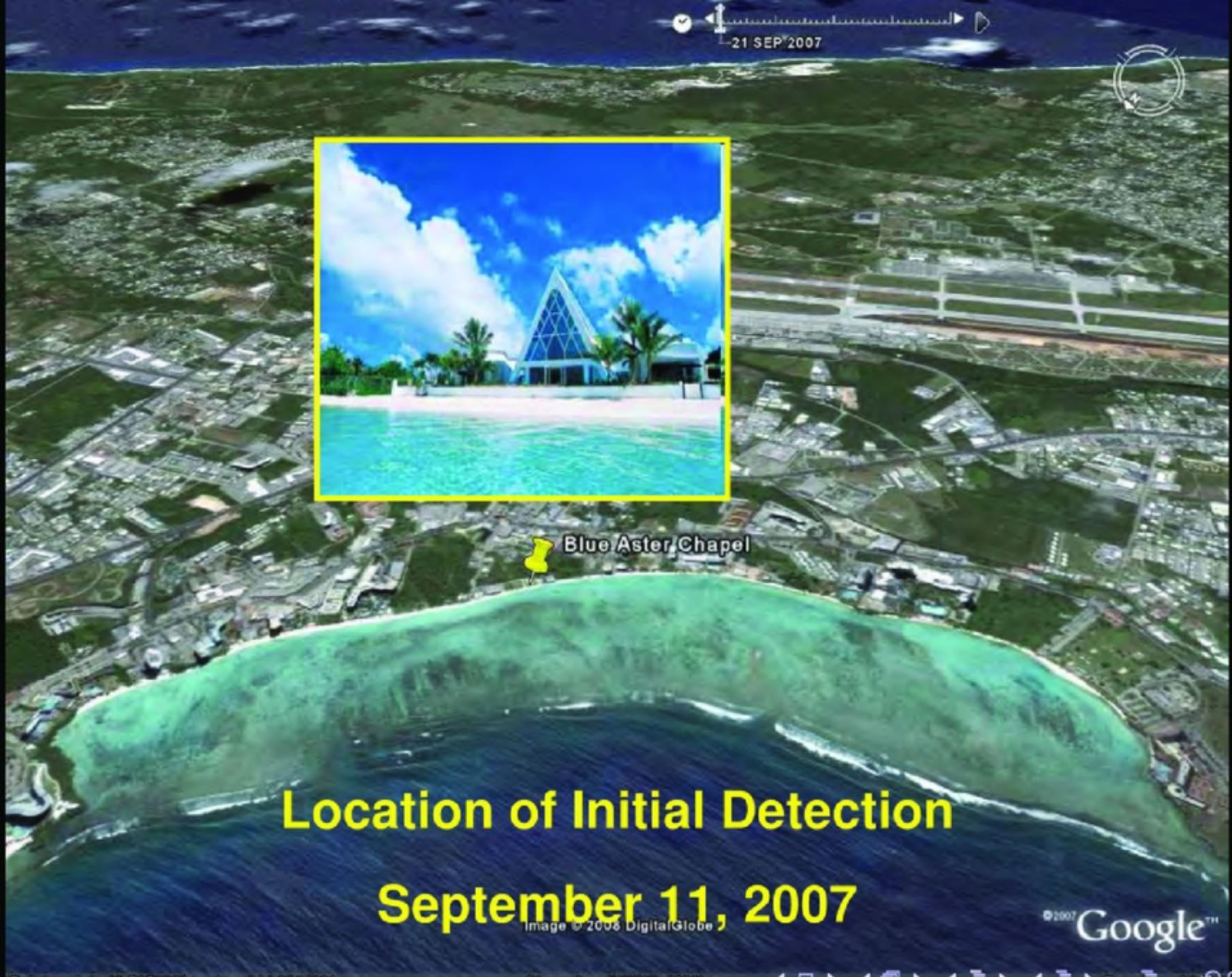
LARVAE FEED ON
DEAD TREES



Coconut palms killed by *Oryctes rhinoceros*; Viti Levu Island, Fiji; 1973
Source: ?



Coconut palms killed by *Oryctes rhinoceros*; Peleliu Island, Palau 1951
Source: Gressitt 1953



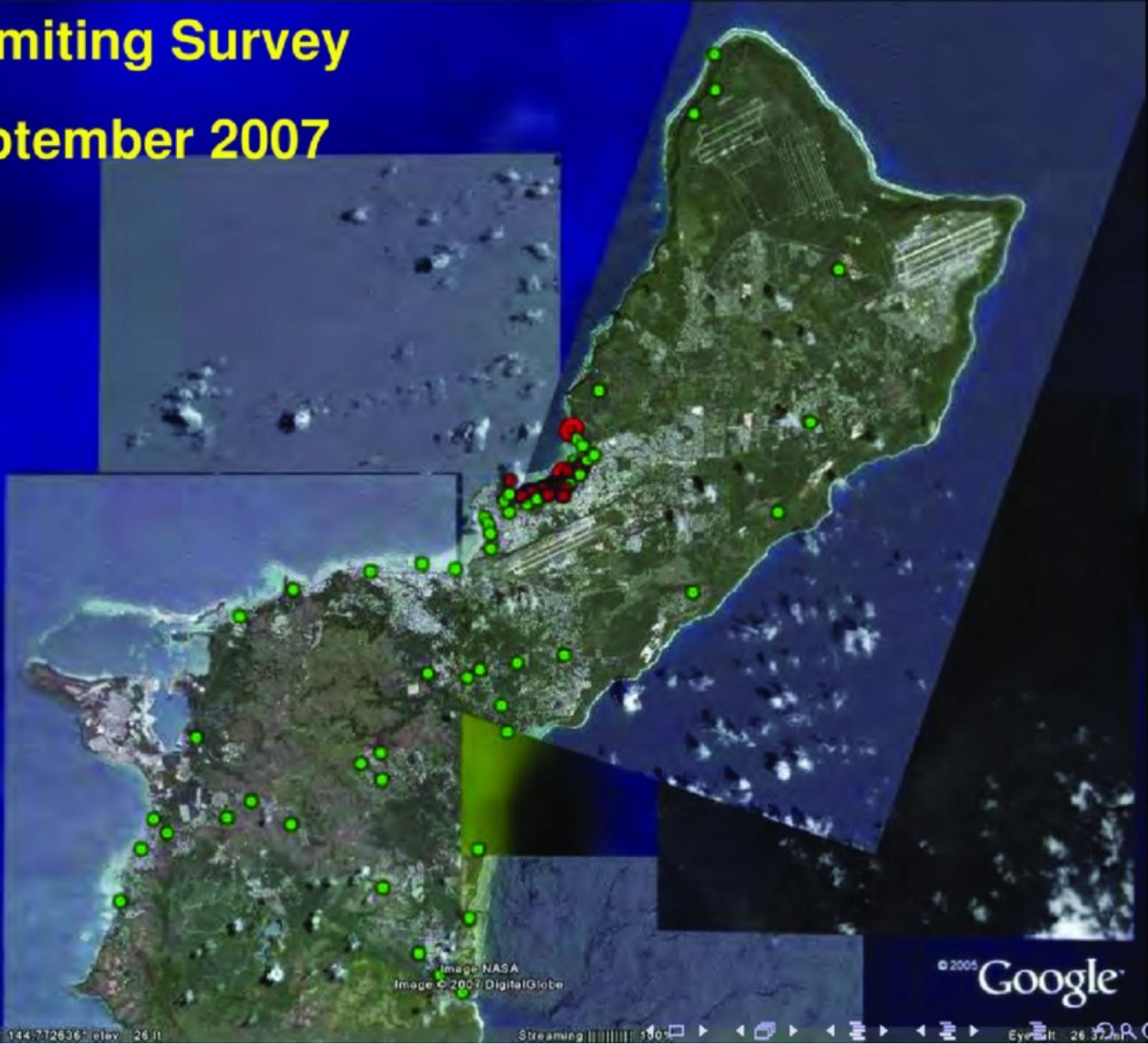
**Location of Initial Detection
September 11, 2007**

Image © 2008 DigitalGlobe

Google™

Delimiting Survey

September 2007



Guam Coconut Rhinoceros Eradication Project

ORGANIZATION

Partners:

USDA-APHIS

Guam Dept. of Agriculture

University of Guam

Funding:

USDA-APHIS

US Forest Service

GovGuam



Guam Coconut Rhinoceros Eradication Project

TACTICS

Quarantine

Limit accidental transportation to uninfested parts of Guam.

Pheromone Traps

Capture adults and detect spread of the beetle population

Sanitation

Kill immatures and remove breeding sites

Detector Dogs

Efficient discovery of breeding sites.

Chemical Control

Injectable systemics for adults; spot treatments for breeding sites.

Biocontrol

Autodissemination of *Oryctes* virus



Initial Quarantine Area

September 2007



Image © 2007 DigitalGlobe

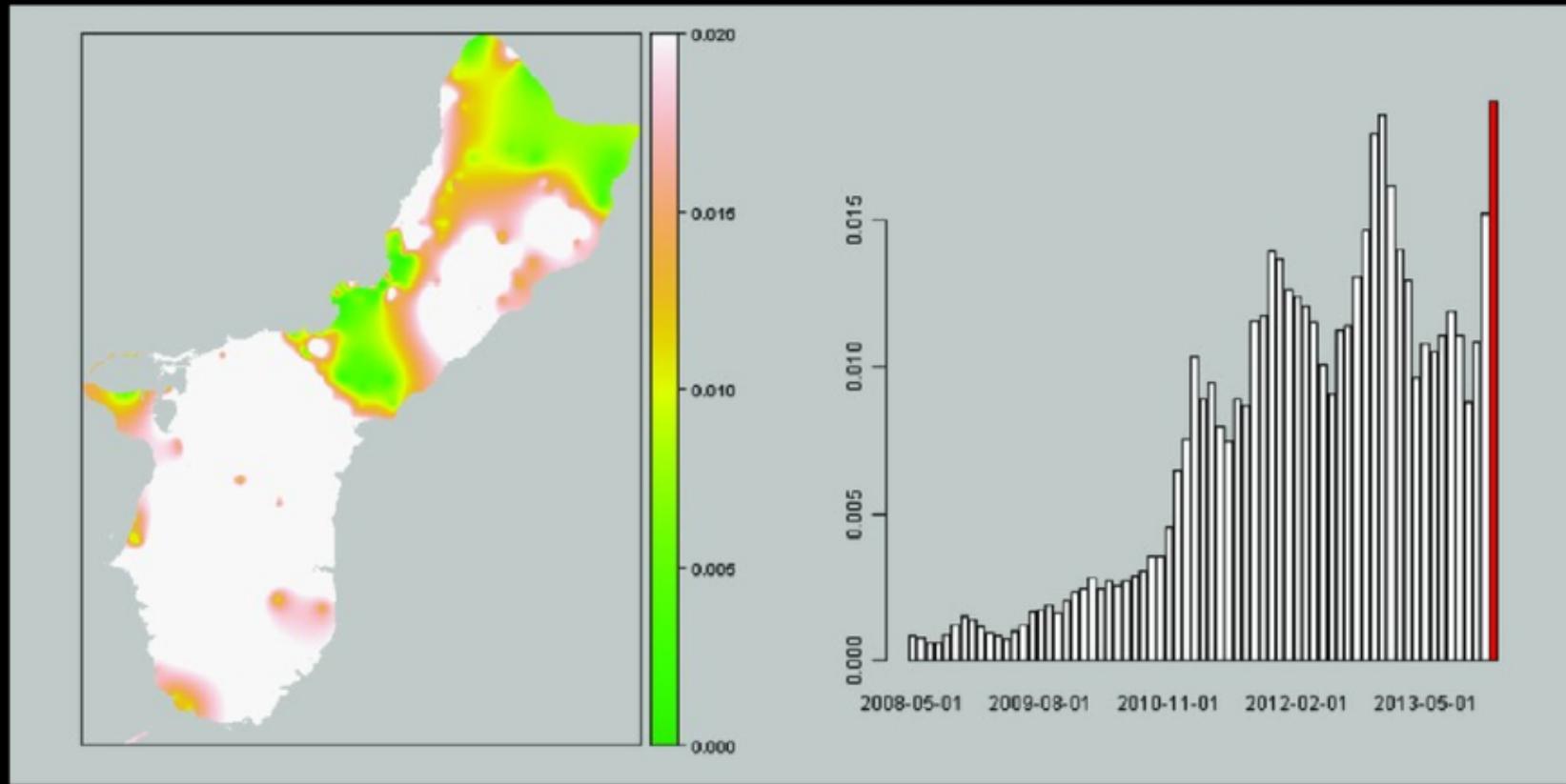
©2007 Google™

PHEROMONE TRAPS

- Mass trapping unsuccessful
- Traps useful for monitoring



90 day trapping period ending on 01 Jan 2014



Mean number of beetles caught per trap-day

Enhanced Pheromone Trap: >3X Standard Trap Catch



Barrel Trap V2: >10X Standard Trap Catch



Sanitation









**GRUBS – 296
PUPAE – 41
ADULTS - 15**



DANGER
**RESTRICTED
AREA**



2007/12/09

DETECTOR DOGS



CHEMICAL CONTROL



Insecticides Being Evaluated

- ▶ CYPERMETHRIN: quick knockdown of all stages; not persistent
- ▶ PYRIPROXIFEN (NYGARD®): insect growth regulator; prevents production of adults
- ▶ SPLAT RB® + CYPERMETHRIN: experimental attracticide; adults only

Spraying Crowns with DEMON MAX (Cypermethrin)



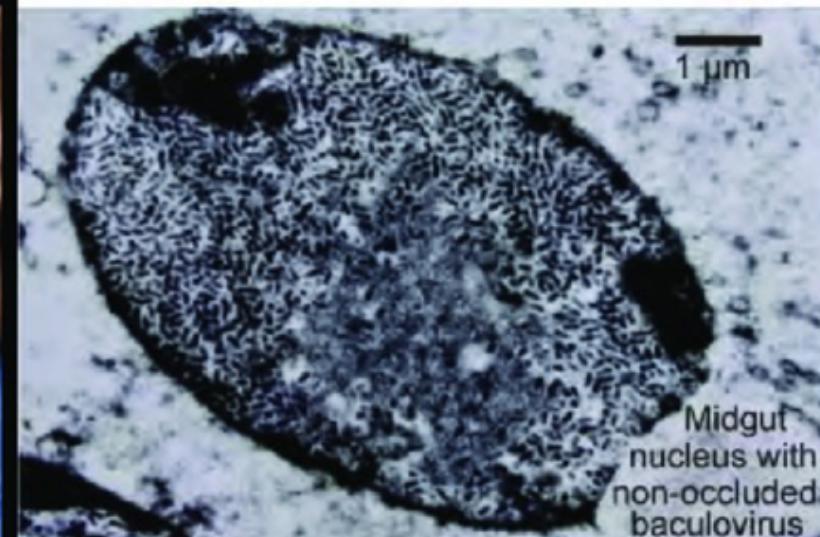
Efficacy of Crown Spraying



BIOCONTROL



Palm rhinoceros beetle



Midgut
nucleus with
non-occluded
baculovirus

Biological Control of the Coconut Rhinoceros Beetle



Major Animal Invaders of Guam's Forests

- Ungulates: deer, pigs, caribao
- Brown treesnake
- Asian Cycad Scale and Associates
- Coconut Rhinoceros Beetle
- Little Fire Ant

Little Fire Ant, *Wasmannia auropunctata*



Photographer: Gracen Brilmyer; Downloaded from [AntWeb](#)

Little Fire Ant, *Wasmannia auropunctata*



Little Fire Ant, *Wasmannia auropunctata*

- Detected November 2011
- Currently at >12 locations
- No control work has been done to date
- Probable effects in infested areas:
 - Most other animals will be extirpated from infested areas
 - Damage from honey dew producing hemipteran populations will increase
 - Agricultural and recreational activities will be curtailed

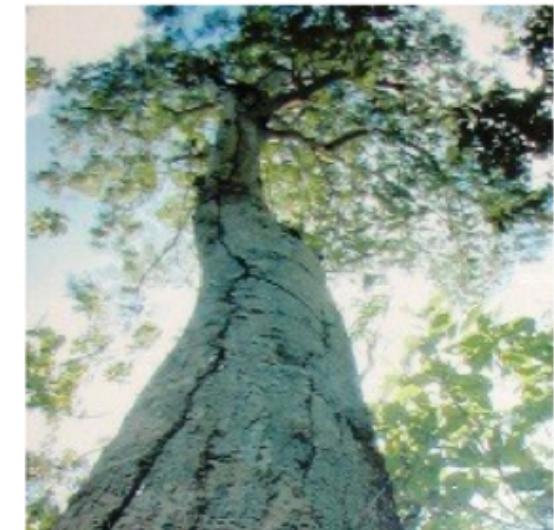
Other Animal Invaders of Concern

- Termites
- Hemipterans
- Bark beetles
- Erythrina gall wasp
- Casuarina gall wasp
- Snails and slugs

Asian Subterranean Termite, *Coptotermes gestroi*



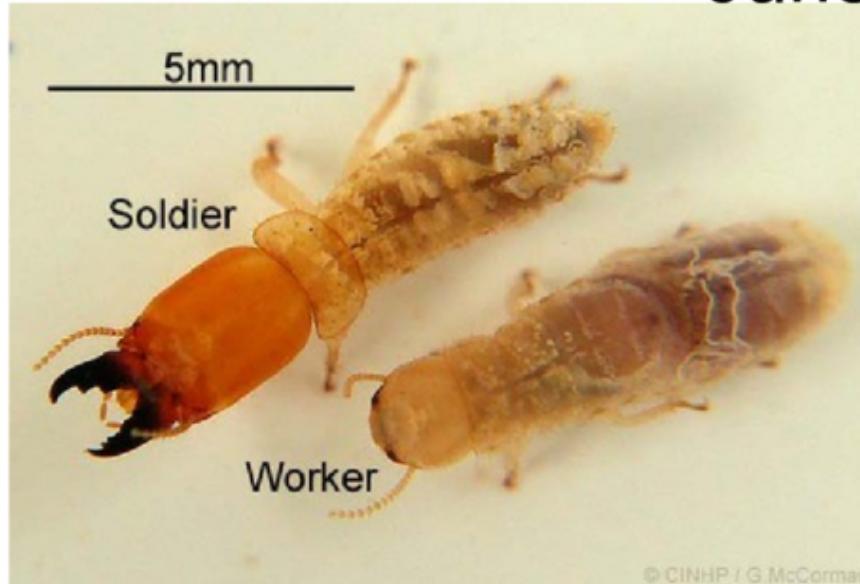
Nasutitermes luzonicus



Mud tube on *Serianthes nelsonii*

Coconut termite, *Neotermes rainbowii*

Detected on Kosrae, Federated States of Micronesia, June 2013



Other Animal Invaders of Concern

- Termites
- **Hemipterans**
- Bark beetles
- Erythrina gall wasp
- Casuarina gall wasp
- Snails and slugs

New Insect Pests Detected on Guam Since Jan. 2002

<i>Paracoccus marginatus</i>	papaya mealybug	2002
<i>Aulacaspis yasumatsui</i>	Asian cycad scale	2003
<i>Myllocerus sp.</i>	calamansi weevil	2004
<i>Pseudaulacaspis cockerelli</i>	false oleander scale	2004
<i>Metaleurodes cardini</i>	Cardin's whitefly	2004
<i>Nipaecoccus nipae</i>	coconut mealybug	2004
<i>Orthezia insignis</i>	greenhouse ensign coccid	2004
<i>Aleurotrachelus trachoides</i>	neotropical solanum whitefly	2004
<i>Chilades pandava</i>	cycad blue butterfly	2005
<i>Daphnis nerii</i>	oleander hawk moth	2005
<i>Quadraesticus erythrinae</i>	Erythrina gall wasp	2006
<i>Lepisiota frauenfeldi</i>	ant	2006
<i>Diaphorina citri</i>	Asian citrus psyllid	2007
<i>Tetraleurodes acaciae</i>	acacia whitefly	2007
<i>Henosepilachna sp.</i>	cucurbit lady beetle	2007
<i>Oryctes rhinoceros</i>	coconut rhinoceros beetle	2007



Other Animal Invaders of Concern

- Termites
- Hemipterans
- Bark beetles
- Erythrina gall wasp
- Casuarina gall wasp
- Snails and slugs

Bark Beetles, Scolytidae



New records of bark beetles from a single coffee berry borer trap operated by Aubrey Moore at the University of Guam Yigo Agricultural Experiment Station, January through February, 2011. Species determined by Donald Bright, Colorado State University. The trap caught seven species of scolytids, four of which are new island records:

1. *Coccotrypes advena* Blandford
2. *Hypothenemus burmanus* (Eicho)
3. *Hypothenemus crudiae* (Panzer)
4. *Xylosandrus crassiusculus* (Motschulsky)



Other Animal Invaders of Concern

- Termites
- Hemipterans
- Bark beetles
- **Erythrina gall wasp**
- Casuarina gall wasp
- Snails and slugs

Erythrina Gall Wasp, *Quadristichus erythrinae*



Image by Walter Nagamine

Erythrina Gall Wasp, *Quadristichus erythrinae*

Not a serious problem on Guam.

No endemic *Erythrina*.

Erythrina variegata is the larval host for the fruit piercing moth, *Eudocima phalonia*, which is a major agricultural pest.



Other Animal Invaders of Concern

- Termites
- Hemipterans
- Bark beetles
- Erythrina gall wasp
- Casuarina gall wasp
- Snails and slugs

Casuarina Gall Wasp, *Selitrichodes casuarinae* La Salle 2014



Undescribed wasp: (genus *Selitrichodes*,
Eulophidae: Tetrastichinae) Photo: A.
Moore, University of Guam, Extension



Other Animal Invaders of Concern

- Termites
- Hemipterans
- Bark beetles
- Erythrina gall wasp
- Casuarina gall wasp
- Snails and slugs

Cuban Slug, *Veronicella cubensis*



- Time lapse videos made with a trail cam equipped with an infrared flash reveal high nocturnal activity of Cuban slugs, snails, and greenhouse frogs on the limestone forest floor.
- Possibly, the slugs are doing major damage to seedlings.

Click on the following link to see an infrared time lapse of limestone forest floor at night.

<https://www.youtube.com/watch?v=6lLw0Cd9awA>

Recurring Themes

- Tropical islands are susceptible to biological invasions.
- Globalization, air transport, and lax biosecurity have negated benefits of geographical isolation.
- Smaller islands are more susceptible to damage from invasive species than larger islands. Larger islands usually have a larger guild of predators and parasites.
- Damage done by invasive species is unpredictable – depends on pre-existing conditions. (Cycad scale a minor problem in HI but a major problem in the Marianas; erythrina gall wasp a major problem in HI, minor problem in the Marianas).
- There is almost always a need for some applied research.

Impediments to Responding to Invasive Species in Micronesia

- Lack of professional capacity: Only 3 PhD level entomologists and 1 PhD level plant pathologist are active in Micronesia. Down from 9 and 3 respectively.
- Detection rates have increased by an order of magnitude. Currently 1 new island record per month.
- There is no emergency funding for rapid response.

Ecological Disasters on Guam

- Brown treesnake (arrived around 1945)
 - Killed most of Guam's birds and small mammals.
 - Caused 7 bird extinctions.
- Asian Cycad Scale (detected 2003)
 - Threatens survival of Guam's endemic cycad.
- Coconut Rhinoceros Beetle (detected 2007).
 - Threatens Guam's coconuts and other palms.
- Little Fire Ant (detected 2011)
 - Threatens most animals remaining in Guam's forests.

Dominant Trees in Guam's Forests are Threatened by Asian Cycad Scale (ACS) and Coconut Rhinoceros Beetle (CRB)

Threat	Species	Status	Tree count ¹	% of total tree count
ACS	<i>Cycas micronesica</i>	endemic	1,571,556	16%
CRB	<i>Cocos nucifera</i>	native	1,162,494	12%
CRB	<i>Heterospathe elata</i>	introduced	1,075,552	11%
	<i>Vitex parviflora</i>	introduced	902,990	9%
	<i>Leucaena leucocephala</i>	introduced	890,217	9%

Tree census data source: J. A. Donnegan et al. 2004. Guam's Forest Resources, 2002. Available from:

http://www.fs.fed.us/pnw/pubs/pnw_rb243.pdf

¹Estimated number of trees with DBH greater than 5 inches.

Invasive species aren't all bad.
They provide job security for biologists.

