

# Biological Invasion of Guam's Forests

Aubrey Moore

College of Natural and Applied Sciences  
University of Guam

SWCD 2021 Educators Symposium  
Healthy Forests, Healthy Communities  
Guam, July 30, 2021

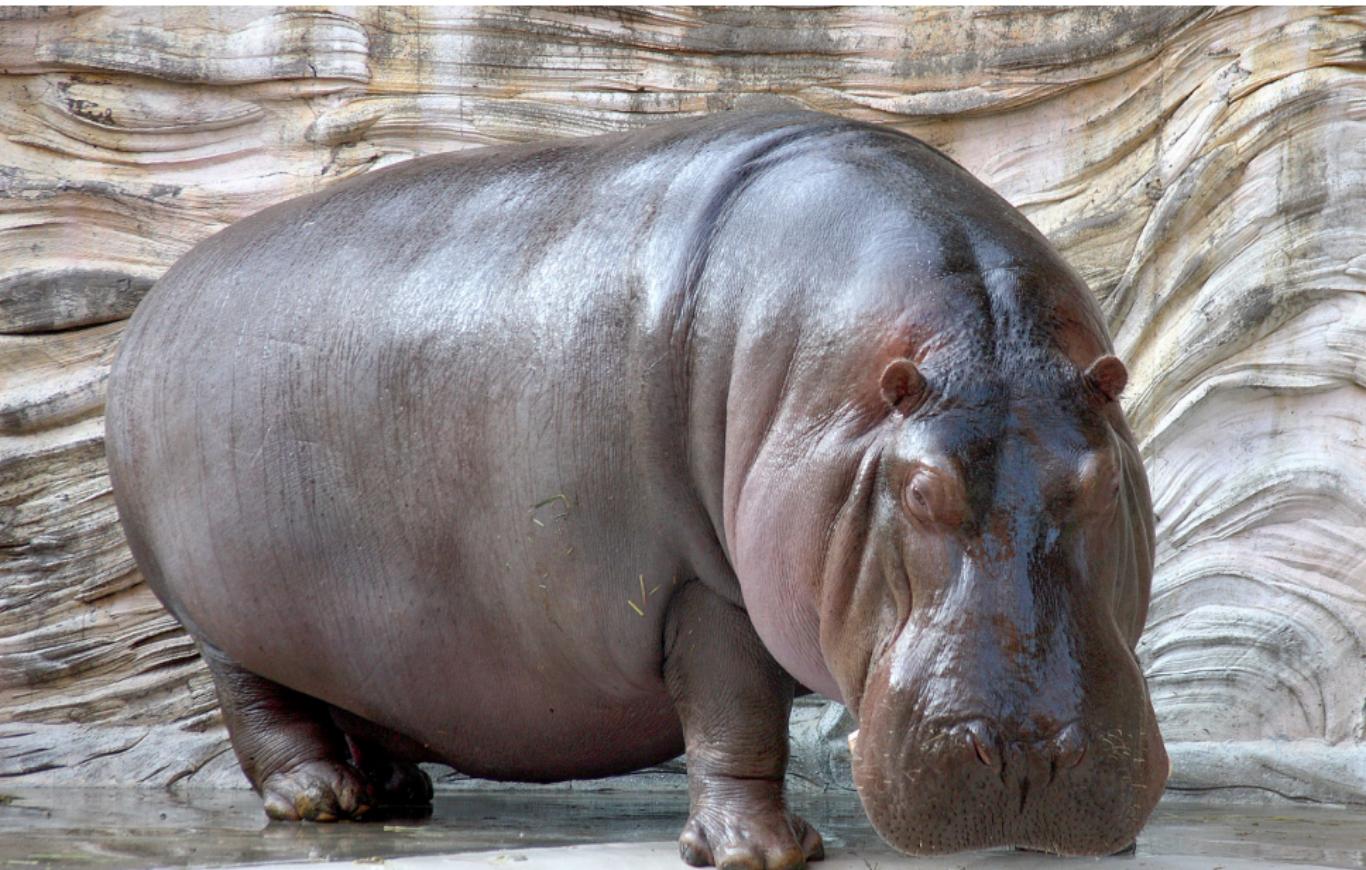
<https://github.com/aubreymoore/SWCD-2021-07-30/raw/main/SWCD-2021-07-30.pdf>



Hafa Adai



# HIPPO Threatens Guam's Biodiversity!



# HIPPO Threatens Guam's Biodiversity!



- H Habitat loss
- I Invasive Species
- P Pollution
- P Human Population
- O Overharvesting

# Definition of 'Invasive Species'



**Invasive species** means an **alien** species whose introduction does or is likely to cause economic or environmental **harm** or harm to human health.

Executive Order 13112

President William Clinton

February 3, 1999

**invasive species** were previously referred to as **exotic pests**

Small tropical islands are susceptible to damage by invasive species



- no winter
- no predators, parasites, or diseases: 'escape from natural enemies'

# Invasive Species Arrival Rate



# Kahalui Airport Pest Risk Assessment (KARA)

- comprehensive inspection of all agricultural produce was performed on 130 days between September 2000 and July 2001
- specimens were identified to species



- 125 species of pest insects and 16 plant diseases not previously known to occur in the State of Hawaii were intercepted at Kahului during the 130 days of KARA inspections
- >1 new invasive species arrived every day!

<http://www.hawaiiaag.org/PQ/KARA20Report20Final.pdf>

# Number of invasive species on Guam

- Almost all of Guam's pests are invasive species
- **One third** of the "**100 World's Worst Invasive Species**" list published by the IUCN Invasive Species Specialist Group occur on Guam
- **One half** of the "**10 World's Most Costly Invasive Species**" occur on Guam

# World's 100 Worst Invasive Species

## 100 OF THE WORLD'S WORST INVASIVE ALIEN SPECIES

### MICRO-ORGANISM

avian malaria  
**banana bunchy top virus**  
 rinderpest virus

(*Plasmodium relictum*)  
 (*Banana bunchy top virus*)  
 (*Rinderpest virus*)

### MACRO-FUNGI

chestnut blight  
 crayfish plague  
 Dutch elm disease  
 frog chytrid fungus  
 phytophthora root rot

(*Cryphonectria parasitica*)  
 (*Aphanomyces astaci*)  
 (*Ophiostoma ulmi*)  
 (*Batrachochytrium dendrobatidis*)  
 (*Phytophthora cinnamomi*)

### AQUATIC PLANT

caulerpa seaweed  
 common cord-grass  
 wakame seaweed  
**water hyacinth**

(*Caulerpa taxifolia*)  
 (*Spartina anglica*)  
 (*Undaria pinnatifida*)  
 (*Eichhornia crassipes*)

### LAND PLANT

**African tulip tree**  
 black wattle  
**Brazilian pepper tree**  
 cogon grass  
 cluster pine  
**creep pricklypear**  
 fire tree  
 giant reed  
 gorse  
 hiptage  
 Japanese knotweed  
 Kahili ginger  
 Koster's curse  
 kudzu  
**lantana**  
 leafy spurge  
**leucosceles**  
 melaleuca  
 mesquite  
 miconia  
**mile-a-minute weed**  
**monosa**  
 privet  
 pumpwood  
 purple loosestrife  
 quinine tree  
 shoebutton aadisia

(*Spathodea campanulata*)  
 (*Acacia mearnsii*)  
 (*Schinus terebinthifolius*)  
 (*Imperata cylindrica*)  
 (*Pinus pinaster*)  
 (*Opuntia stricta*)  
 (*Myrica faya*)  
 (*Arundo donax*)  
 (*Ulex europeus*)  
 (*Hiptage benghalensis*)  
 (*Filopanax japonicus*)  
 (*Hedychnium gardnerianum*)  
 (*Cleidion hirta*)  
 (*Pueraria montana* var. *lobata*)  
 (*Lantana camara*)  
 (*Euphorbia corollata*)  
 (*Erechtites hieracifolia*)  
 (*Melaleuca quinquenervia*)  
 (*Prosopis glandulosa*)  
 (*Miconia calvescens*)  
 (*Milanea microstachya*)  
 (*Monsonia pigra*)  
 (*Ligustrum robustum*)  
 (*Cercropia pelata*)  
 (*Lythrum salicaria*)  
 (*Cinchona pubescens*)  
 (*Ardisia elliptica*)

### LAND PLANT (CONTINUED)

Stink weed  
 strawberry guava  
 tamarike  
**wedelia**  
 yellow Himalayan raspberry

(*Chromolaena odorata*)  
 (*Psidium cattleianum*)  
 (*Tamarix ramosissima*)  
 (*Sphagneticola trilobata*)  
 (*Rubus ellipticus*)

### AQUATIC INVERTEBRATE

Chinese mitten crab  
 comb jelly  
 fish hook flea  
**golden apple snail**  
 green crab  
 marine clam  
 Mediterranean mussel  
 Northern Pacific seastar  
 zebra mussel

(*Eriocheir sinensis*)  
 (*Mnemiopsis leidyi*)  
 (*Cercopagis pengoi*)  
 (*Pomacea canaliculata*)  
 (*Carcinus moorsii*)  
 (*Potamocorbula amurensis*)  
 (*Mytilus galloprovincialis*)  
 (*Asterias amurensis*)  
 (*Dreissena polymorpha*)

### LAND INVERTEBRATE

Argentine ant  
 Asian longhorned beetle  
**Asian tiger mosquito**  
**big-headed ant**  
 common malaria mosquito  
 common wasp  
**crazy ant**  
 cypress aphid  
**flatworm**  
 Formosan subterranean termite  
**giant African snail**  
 gypsy moth  
 khapra beetle  
**little fire ant**  
 red imported fire ant  
**rosy wolf snail**  
 sweet potato whitefly

(*Linepithema humile*)  
 (*Anoplophora glabratipennis*)  
 (*Ataenius albopictus*)  
 (*Pheidole megacephala*)  
 (*Anopheles quadrimaculatus*)  
 (*Vespa vulgaris*)  
 (*Anoplolepis gracilipes*)  
 (*Cinara capparis*)  
 (*Platydemus mankowskyi*)  
 (*Coptoperla formosanus shiraki*)  
 (*Achatina fulica*)  
 (*Lymnaea dispar*)  
 (*Trochodera granarium*)  
 (*Blausimnia punctata*)  
 (*Solenopsis invicta*)  
 (*Engaeus rufus*)  
 (*Bemisia tabaci*)

### AMPHIBIAN

bullfrog  
**cane toad**  
 Caribbean tree frog

(*Rana catesbeiana*)  
 (*Bufo marinus*)  
 (*Eleutherodactylus coqui*)

### FISH

brown trout  
**carp**  
 large-mouth bass

(*Salmo trutta*)  
 (*Cyprinus carpio*)  
 (*Micropterus salmoides*)

### FISH (CONTINUED)

Mozambique tilapia  
 Nile perch  
 rainbow trout  
**walking catfish**  
 Western mosquito fish

(*Oreochromis mossambicus*)  
 (*Lates niloticus*)  
 (*Oncorhynchus mykiss*)  
 (*Clares batrachus*)  
 (*Gambusia affinis*)

### BIRD

Indian myna bird  
 red-vented bulbul  
 starling

(*Acridotheres tristis*)  
 (*Pycnonotus cafer*)  
 (*Sturnus vulgaris*)

### REPTILE

brown tree snake  
 red-eared slider

(*Bronia irregularis*)  
 (*Trachemys scripta*)

### MAMMAL

brush-tail possum  
**domestic cat**  
**goat**  
 grey squirrel  
 macaque monkey  
**mouse**  
 nutria  
**pig**  
 rabbit  
 red deer  
 red fox  
**ship rat**  
 small Indian mongoose  
 stoat

(*Trichosurus vulpecula*)  
 (*Felis catus*)  
 (*Capra hircus*)  
 (*Sciurus carolinensis*)  
 (*Macaca fascicularis*)  
 (*Mus musculus*)  
 (*Myocastor coypus*)  
 (*Sus scrofa*)  
 (*Oryctolagus cuniculus*)  
 (*Cervus elaphus*)  
 (*Vulpes vulpes*)  
 (*Rattus rattus*)  
 (*Herpestes javanicus*)  
 (*Mustela erminea*)

Species were selected for the list using two criteria: their serious impact on biological diversity and/or human activities, and their illustration of important issues of biological invasion. To ensure a wide variety of examples, only one species from each genus was selected. **Absence from the list does not imply that a species poses a lesser threat.**

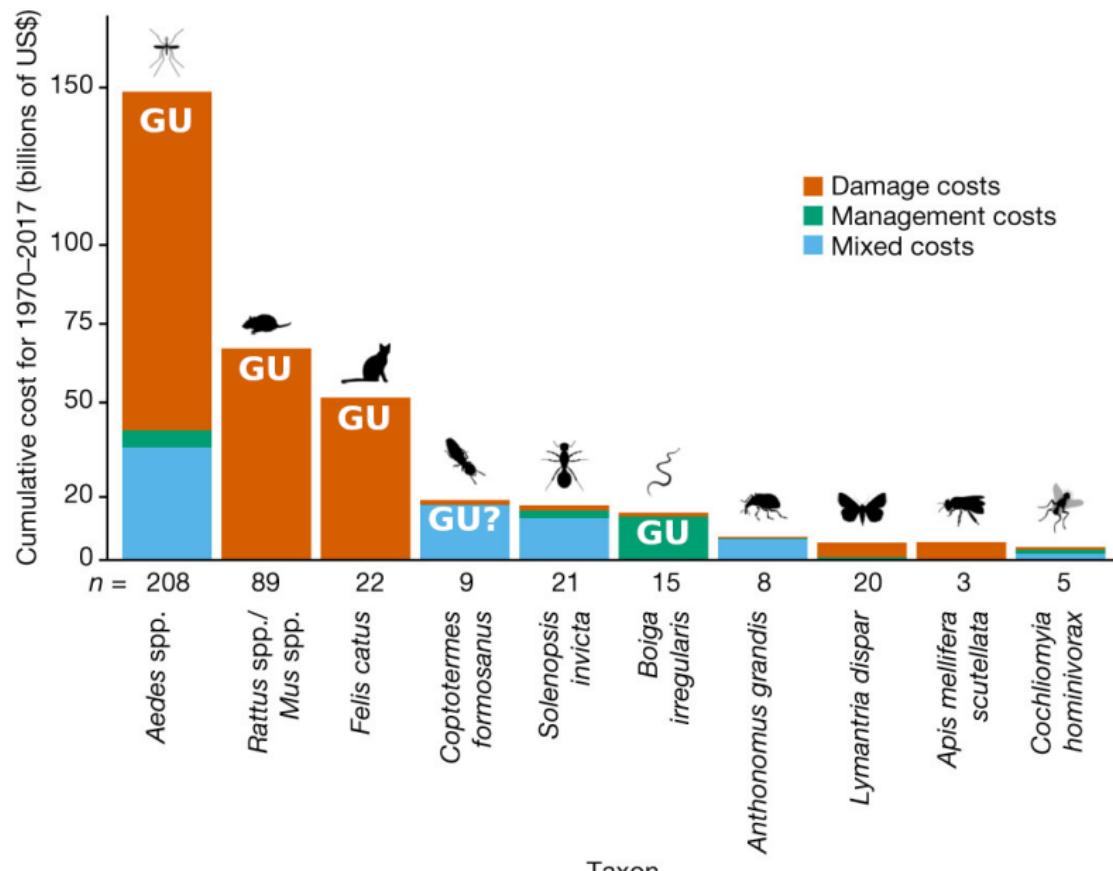
Development of the 100 of the World's Worst Invasive Alien Species list has been made possible by the support of the Fondation d'Entreprise TOTAL (1998 - 2000).

For further information on these and other invasive alien species consult The Global Invasive Species Database:

[www.iissg.org/database](http://www.iissg.org/database)



# World's 10 Most Costly Invasive Species

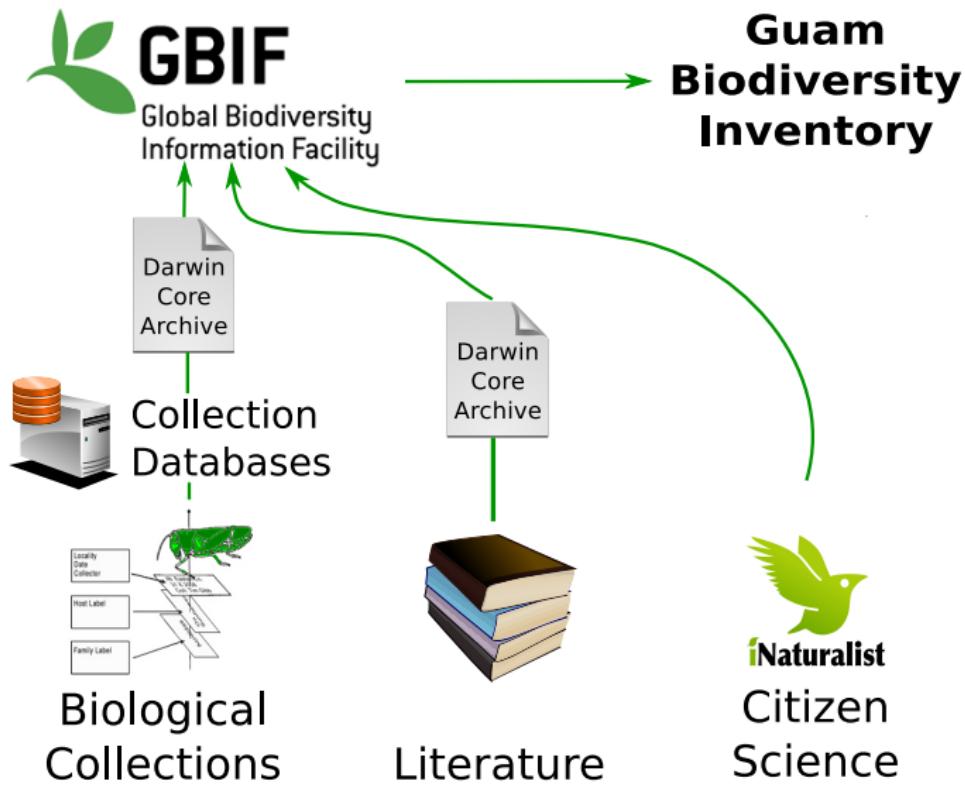


# Impediments to Dealing with Invasive Species on Guam

- We suffer from the "**taxonomic impediment**".
- Professional capacity is inadequate.
- Even when we manage to detect invasive species, our findings are rarely published in the scientific literature.
- Guam lacks a terrestrial biodiversity inventory.

Arrival of and impacts of invasive species on small islands are grossly under-reported.

# Design for a Guam Terrestrial Biodiversity Inventory



# Major Biological Invasions 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, listed as the most numerous tree on Guam in the 2002 Forest Service survey.
- Coconut Rhinoceros Beetle (detected 2007).
  - Threatens coconut palms, listed as the 2nd most numerous tree on Guam in the 2002 Forest Service survey.
- Little Fire Ant (detected 2011)
  - Threatens most animals remaining in Guam's forests.

# Bird extinction by brown treesnake



Courtesy of USGS

# Forest Birds before BTS



# Forest Birds after BTS



# Loss of Ecosystem Services Provided by Birds



EurekAlert!  
The Global Source for Science News



AAAS

HOME NEWS MULTIMEDIA MEETINGS PORTALS ABOUT

PUBLIC RELEASE: 9-JUL-2018

## Birds eat 400 to 500 million tonnes of insects annually

*Along with spiders, insectivorous birds play a vital role in consuming insects that would otherwise destroy forests or crops*

"Birds are an endangered class of animals ... we must fear that the vital ecosystem services that birds provide - such as the suppression of insect pests - will be lost." says Nyffeler.

## BTS - Current Status

- Millions of dollars per year are spent on preventing BTS from leaving Guam.
- Some funds are being used for control methods development: snake-proof barriers and "pinkies on parachutes".

# Asian Cycad Scale



Asian cycad scale, *Aulacaspis yasumatsui* (HEMIPTERA: DIASPIDIDAE)

# Asian Cycad Scale - Origin and Pathway

- Origin: Southeast Asia
- Florida
- Hawaii 1998
- Guam 2003
- Rota 2005?
- Palau 2005?

# Asian Cycad Scale

## Scale Morphology & Life History

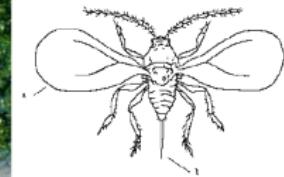


Eggs

Male  
cocoon

Female

Crawlers



Adult male

# Asian Cycad Scale



# Asian Cycad Scale



# Asian Cycad Scale



# Asian Cycad Scale



# Asian Cycad Scale



# Asian Cycad Scale



# Asian Cycad Scale



# Asian Cycad Scale



# Asian Cycad Scale



# Asian Cycad Scale



# Asian Cycad Scale



# Asian Cycad Scale



# Asian Cycad Scale



# Asian Cycad Scale

2013-02-10

ENCYRTIDAE

*Arrhenophagus?* sp.

parasitizing male

*Aulacaspis ysumatsui*

infesting *Cycas*

*micronesica*



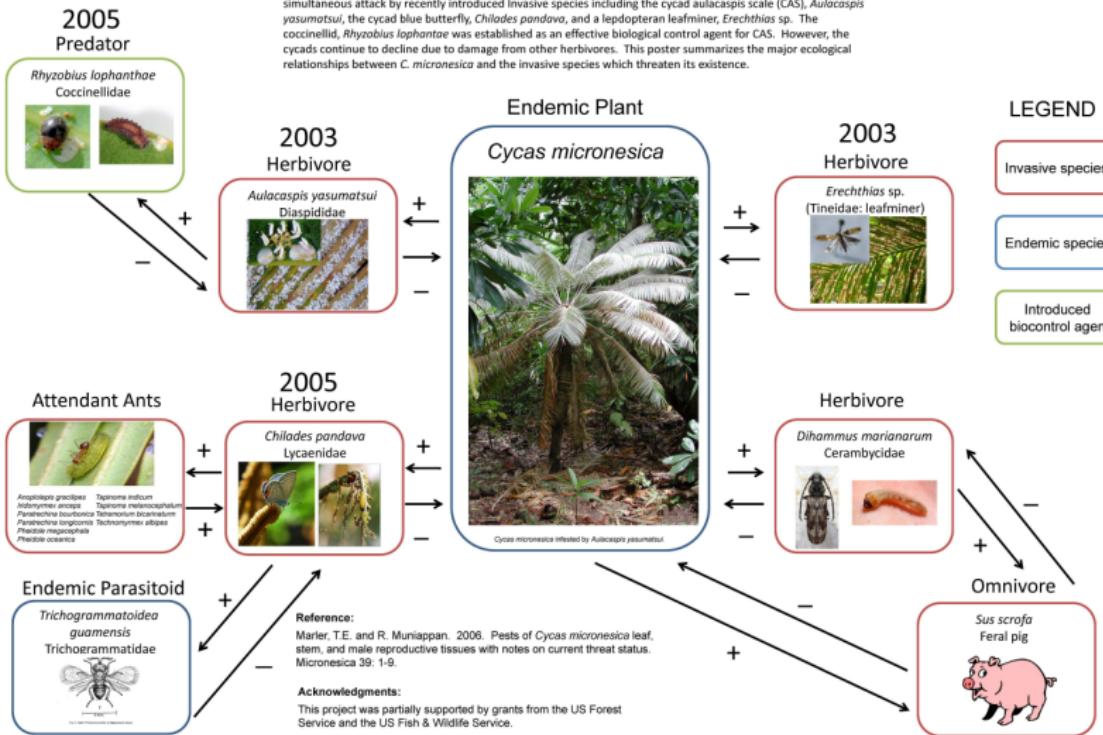
# Massive mortality of *Cycas micronesica* by invasive species

## A Coalition of Invasive Species Attacks Guam's Native Cycads

Aubrey Moore\*, Ross Miller, and Thomas Marler

Western Pacific Tropical Research Center, University of Guam, Mangilao Guam 96923

A 2002 forest survey listed *Cycas micronesica* as the most numerous tree-sized plant in Guam's forests. In 2006 *C. micronesica* was placed on the IUCN Red List of Threatened Species in response to high mortality from simultaneous attack by recently introduced invasive species including the cycad aulacaspis scale (CAS), *Aulacaspis yasumatsui*, the coccinid beetle, *Rhyzobius lophanthae*, and a lepidopteran leafminer, *Erechthias* sp. The coccinid, *Rhyzobius lophanthae* was established as an effective biological control agent for CAS. However, the cycads continue to decline due to damage from other herbivores. This poster summarizes the major ecological relationships between *C. micronesica* and the invasive species which threaten its existence.



# Asian Cycad Scale - Current Status on Guam

- 90% of Guam's endemic cycads have been killed by the scale and other invasive species
- Mature plants are protected by the biocontrol beetle, but no natural reproduction is occurring
- *Cycas micronesica* placed on the US National Endangered Species List in 2015. (Was the most abundant tree on Guam in 2002.)

# Coconut rhincoceros beetle



*Oryctes rhinoceros* Biotype G

# Geographic Distribution of Coconut Rhinoceros Beetle

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

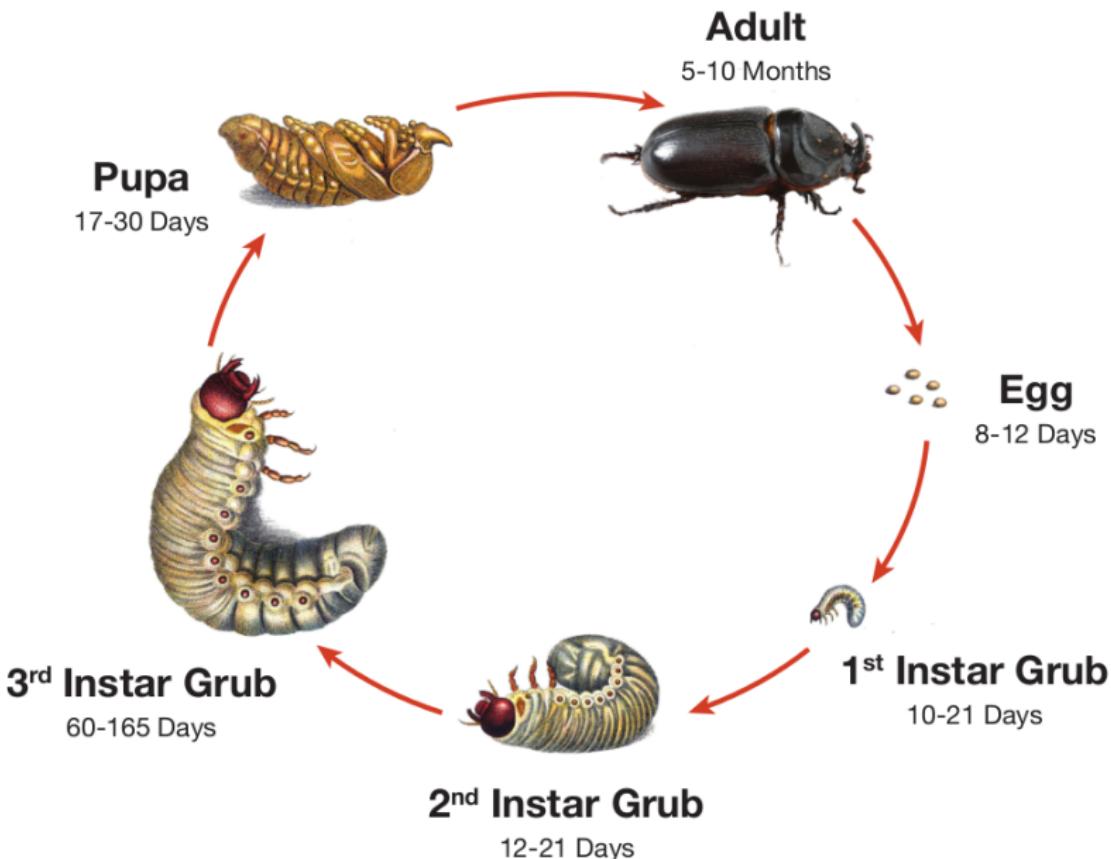
© Mapbox © OpenStreetMap Improve the underlying map



map.geojson rendered with ❤ by GitHub

<http://aubreymoore.github.io/crbdist/mymap.html>.

# Coconut Rhinoceros Beetle Life Cycle



## CRB POPULATION GROWTH ASSUMING UNLIMITED RESOURCES

- generation 0: 2
- generation 1: 100
- generation 2: 5,000
- generation 3: 250,000
- generation 4: 12,500,000
- generation 5: 625,000,000
- generation 6: 31,250,000,000

# Coconut rhincoceros beetle



# Coconut rhincoceros beetle



# Coconut rhincoceros beetle

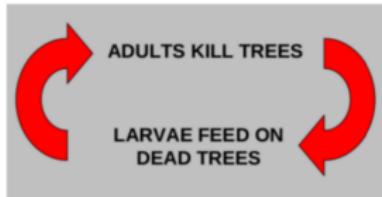


Figure : Coconut palms killed by *Oryctes rhinoceros* in Fiji (photo by Bedford)

# Coconut rhincoceros beetle



- A typhoon leaves large numbers of potential CRB breeding sites
- Large numbers of CRB adults emerge from these sites and kill many coconut palms
- Dead standing coconut palms generate even more CRB adults which kill even more palms.

# Coconut Rhinoceros Beetle - Current Status on Guam

- Mature coconuts and other palms are rapidly being killed by an uncontrolled outbreak of CRB-G which was triggered by Typhoon Dolphin (2015).
- Coconut palm mortality estimates are not available. History from Palau suggests that we will lose 50% or more of our palms if the outbreak is not controlled.
- A search for an effective biological control agent, most likely a new isolate of *Oryctes rhinoceros* nudivirus is under way.
- If current outbreaks of CRB-G cannot be controlled, CRB-G will spread to other islands and possibly the Americas.

# Coconut rhinoceros beetle



# Coconut rhinoceros beetle



Sea level in the Solomons has risen 8 mm per year since 1993.

Source: <https://www.sprep.org/climate-change/sea-level-in-solomon-islands-predicted-to-rise-over-8mm-in-the-coming-century>

# Coconut rhinoceros beetle





Little fire ant, *Wasmannia auropunctata* (HYMENOPTERA: FORMICIDAE)

- Forms supercolonies with multiple queens
- Nests in trees and on ground

# LFA - Biology



# LFA - Biology



*A reaction to little fire ant stings in Papua New Guinea (© Cas Vanderwoude)*



*Little fire ant stings in Papua New Guinea (© Cas Vanderwoude)*

# LFA - Biology



*These domestic animals have been blinded by little fire ants (© Cas Vanderwoude)*



*Little fire ants not only sting, but support sap-sucking insects which encourage plant diseases like the fungus shown here growing on coffee  
© Cas Vanderwoude)*

# Little Fire Ant - Origin and Pathway

- Origin: South America
- Florida 1920s
- Hawaii 1999
- Guam 2011
- Yap 2017

# LFA - Detection on Guam



LFA discovered by CRB crew at Primo Greenwaste Dump Site in Yigo in 2011.

# LFA - Current Status on Guam

- Eradication from Guam is not feasible
- LFA occurs at 20+ dispersed sites on Guam and continues to spread
- Effective ant baits and application methods are available for local control programs

# LFA - Prognosis for Guam

- There are no known biocontrol agents for island-wide control of LFA
- Will impact quality of life for humans and pets
- Possible impacts on tourism
- Impacts on natural ecosystems are unpredictable

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

Threat	Species	Status	Tree count <sup>1</sup>	% 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](http://www.fs.fed.us/pnw/pubs/pnw_rb243.pdf)

<sup>1</sup>Estimated number of trees with DBH greater than 5 inches.

- Guam's forests are dying because two invasive insect species (ACS and CRB) are killing predominant trees (cycads and palms).
- Forest restoration efforts will likely fail if this problem is not solved.
- Implementing effective self-sustaining biological control of ACS and CRB should be a priority.

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



## References

- | Ares, Adrian, director (2021). *Forests of Guam 2021*. Western Pacific Tropical Research Center, University of Guam. URL: <https://www.youtube.com/watch?v=27D-ovSzLBk> (visited on 07/26/2021).
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