

Biological Invasion of Guam's Forests

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Outline

1 Introduction

2 Brown treesnake

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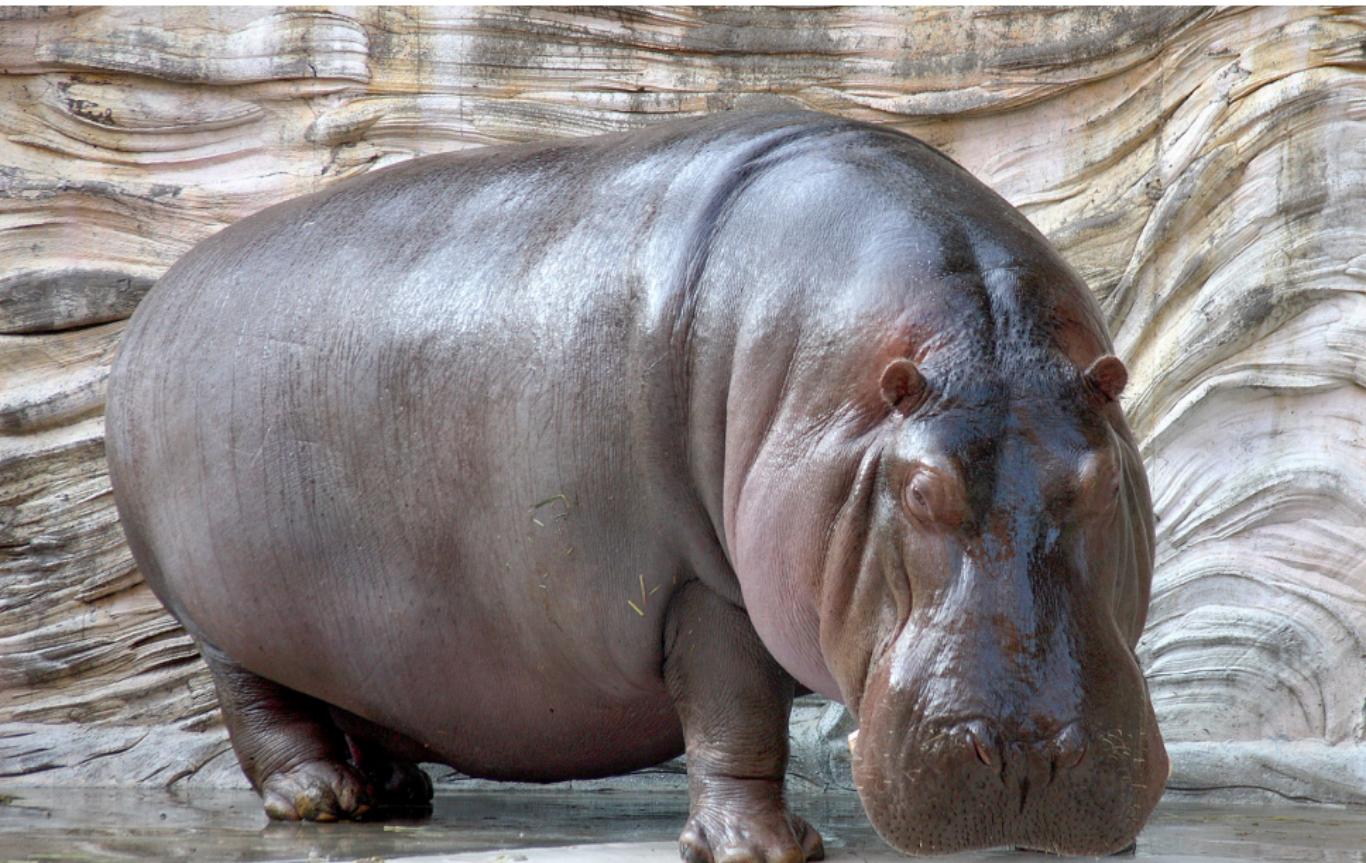
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Introduction

Welcome to Guam



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

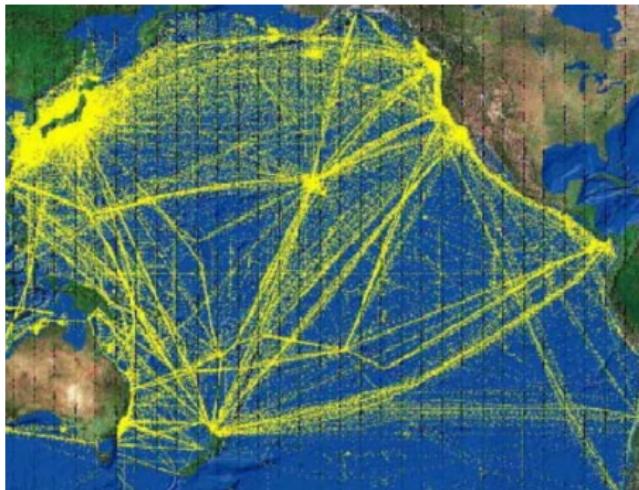
invasive species were previously referred to as **exotic pests**

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
leucaena
 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*)
 (*Fallotia japonica*)
 (*Hedychnium gardnerianum*)
 (*Cleidion hirta*)
 (*Pueraria montana* var. *lobata*)
 (*Lantana camara*)
 (*Euphorbia cusi*)
 (*Erechtites hieracifolia*)
 (*Melaleuca quinquenervia*)
 (*Prosopis glandulosa*)
 (*Miconia calvescens*)
 (*Milania microstachys*)
 (*Morone nigra*)
 (*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 moorsi*)
 (*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*)
 (*Trogedora granarium*)
 (*Blausimnia punctatula*)
 (*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

(*Bronchocela 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.**

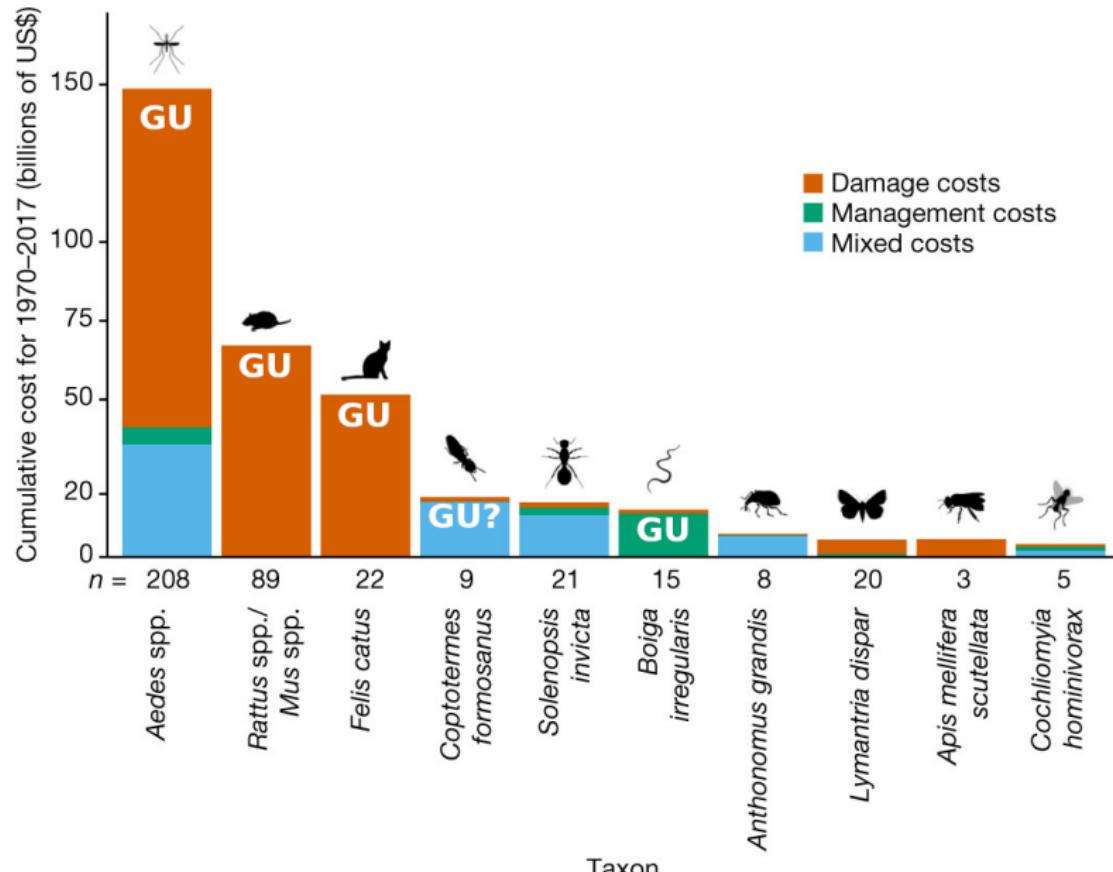
Development of the 100 of the World's Worst Invasive Alien Species list has been made possible by the support of the Fondation d'Entreprise TOTAL (1998 - 2000).

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

www.iissg.org/database



World's 10 Most Costly Invasive Species

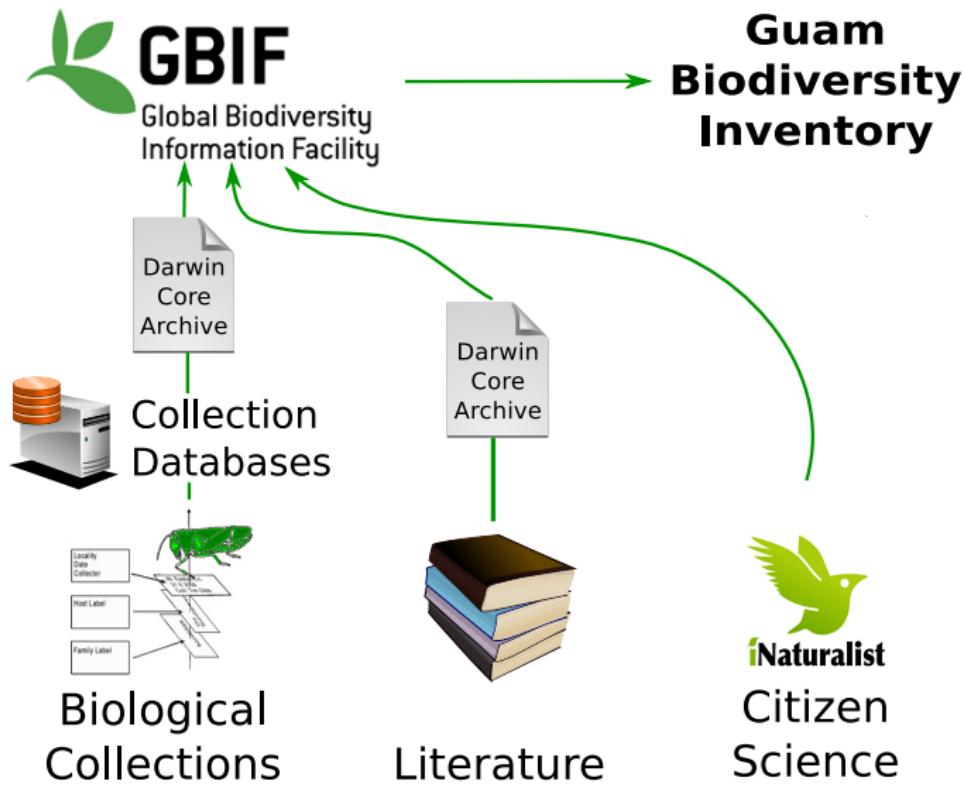


Impediments to Dealing with Invasive Species on Guam

- 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.

Brown treesnake

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

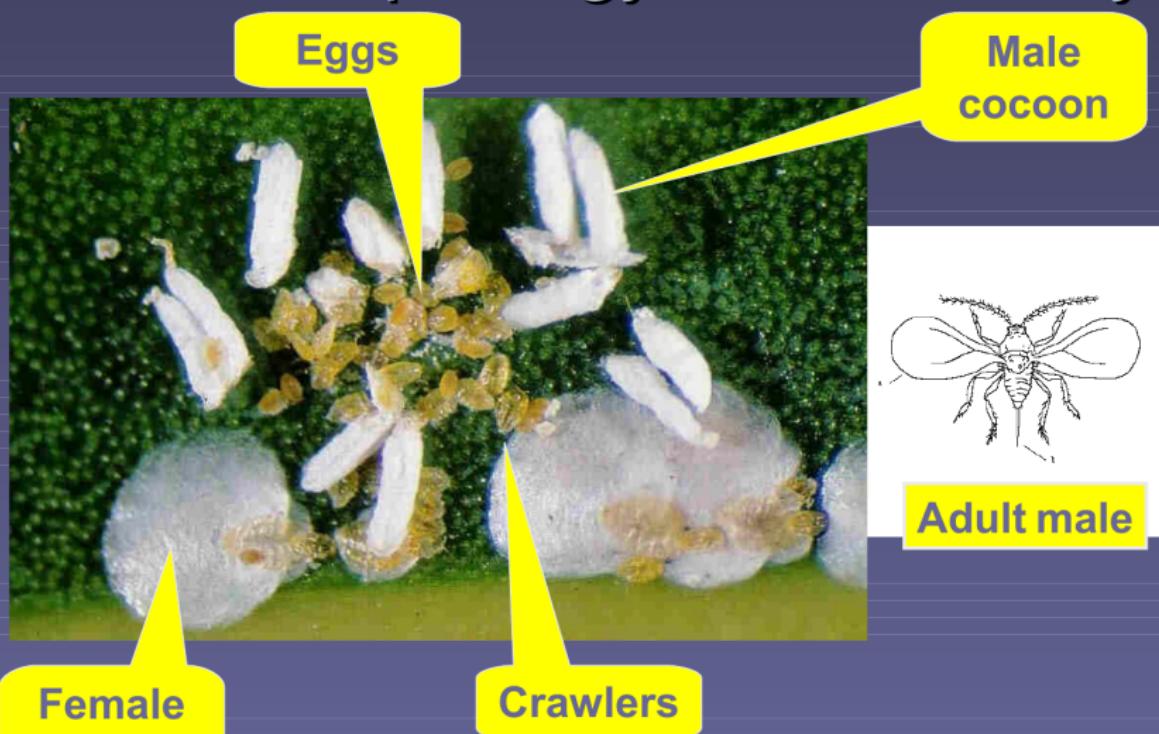


Asian cycad scale, *Aulacaspis yasumatsui* (HEMIPTERA: DIASPIDIDAE)

Asian Cycad Scale - Origin and Pathway

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

Scale Morphology & Life History





























2013-02-10
ENCYRTIDAE
Arrhenophagus? sp.
parasitizing male
Aulacaspis ysumatsui
infesting *Cycas*
micronesica



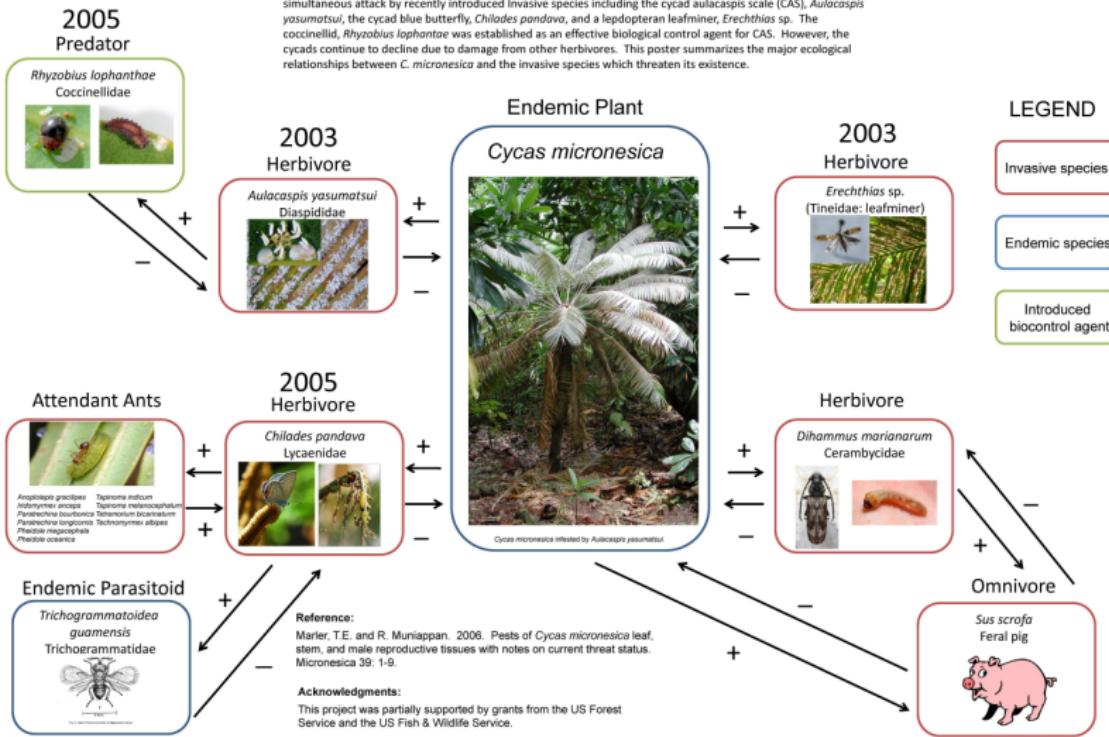
Massive mortality of *Cycas micronesica* by invasive species

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 cycad blue butterfly, *Chilades pandava*, and a lepidopteran leafminer, *Erechthias* sp. The coccinellid, *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 Rhinoceros Beetle

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

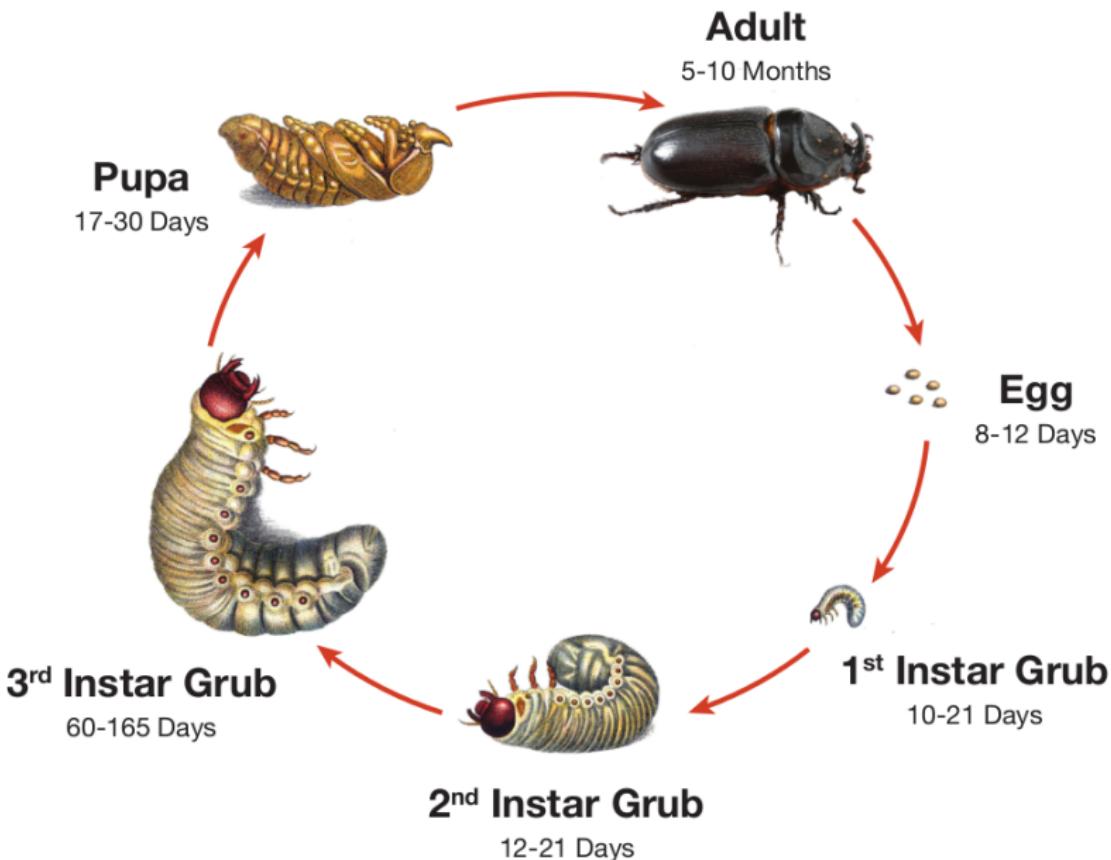


map.geojson rendered with ❤ by GitHub

<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

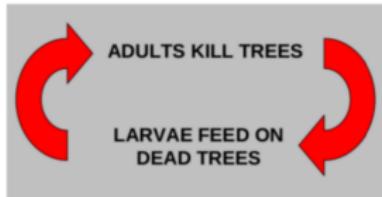


Figure : Coconut palms killed by *Oryctes rhinoceros* in Fiji (photo by Bedford)

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.

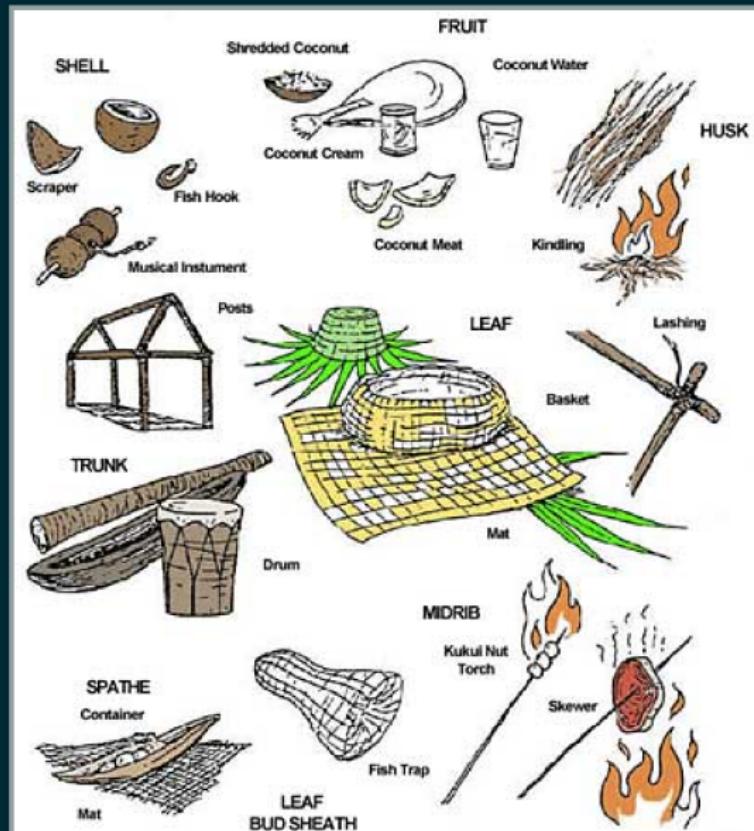
Coconut Rhinoceros Beetle - Current Status on Guam

- Mature coconuts and other palms are rapidly being killed by an uncontrolled outbreak of CRB-G which was triggered by Typhoon Dolpine in 2016
- Damage 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 nudivorus* is under way.
- If current outbreaks of CRB-G cannot be controlled, CRB-G will spread to other islands and possibly the Americas.

LFA - Prognosis for Guam

- A search for an effective biological control agent, most likely a new isolate of *Oryctes rhinoceros* nudivirus is under way.

Coconut rhincoceros beetle



Coconut rhincoceros 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 rhincoceros beetle



Little Fire Ant



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

Conclusions

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.

- 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

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- | Moore, Aubrey (2017). *Guam Forestry Workshop Resources*. GitHub. URL: <https://github.com/aubreymoore/Guam-Forestry-Workshop-Resources> (visited on 07/24/2017).