

# CFES Report

## 2022-06-26 to 2023-06-26

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## Preface

I was hired by the University of Guam on October 1, 2003 under a limited-term, split appointment (50% extension and 50% research). On June 26, 2008, I started a tenure-track appointment as extension entomologist (100% extension) with the academic rank of assistant professor. At the end of the 2012 fall term I applied for tenure and promotion to associate professor and received both in 2013. At the end of 2018 fall term I applied for promotion to full professor and was promoted on July 11, 2019.

I work within the Agriculture and Natural Resources Unit of the University of Guam Cooperative Extension Service. I am a member of the Environmental Science Graduate Program Faculty and a member of the Western Pacific Tropical Research Center.

I anticipate retirement from the University on October 1, 2023.

**Note to Reader:** If you are reading the PDF version of this report on a device connected to the internet, you will be able to follow hypertext links to documents I have referenced.

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## Part I. Role Assignments

### Time and Effort for Each Role

- 51% Extension and Community Activities (ECA)
- 34% Creative/Scholarly Activity or Research (CSR)
- 15% University and Community Service (UCS)

## Part II. Extension and Community Activities (ECA) 51%

### NIFA Classification

#### Critical Issues (CI)

- Sustained Agricultural Production Systems
- Plant Pest Efforts & Protect Resources of Guam

#### NIFA Science Emphasis Areas (SEA)

- **Sustainable Agricultural Production Systems** Addresses human interaction between science, technology, and agriculture. Integrates the biological, physical, and environmental and socioeconomic factors essential to successful production enterprises and viable rural communities.

#### NIFA Knowledge Areas (KA)

- KA 203 – Plant Biological Efficiency and Abiotic Stresses Affecting
- KA 211 – Insects, Mites and Other Anthropods Affecting Plants
- KA 215 – Biological Control of Pests Affecting Plants
- KA 216 – Integrated Pest Management Systems

#### Planned Activities (PA)

- PA1 Insect Diagnostic Services
- PA2 Detection and Documentation of Invasive Species
- PA3 University of Guam Insect Collection
- PA4 Mitigation of Damage to Guam's Ecosystems by Invasive Species

- PA5 National Plant Diagnostic Network (NPDN)
- PA6 Guam Invasive Species Advisory Committee (GISAC) and Guam Invasive Species Council (GISC)
- PA7 Public Outreach: Internet
- PA8 Public Outreach: Presentations
- PA9 Public Outreach: Miscellaneous
- PA10 Public Outreach: Public GitHub Repositories

## ECA-PA1 Insect Diagnostic Services

**Description** As an extension entomologist, a major part of my job is providing insect identification and pest control recommendations to a diverse clientele including commercial growers, gardeners, householders, GovGuam agencies, federal agencies, and UOG colleagues. Most client contacts are initiated by a phone call or a visit by the client to the ANR office. In many cases identification and pest control recommendations require a site visit by me and/or extension associates to collect samples and define the problem.

**Activities** The number of extension calls requiring my assistance averaged approximately one per day during the reporting period. Many of these are documented as postings to iNaturalist [1].

### References

- [1] Aubrey Moore. *Observations posted on iNaturalist by Aubrey Moore between June 26 2022 and June 26 2023*. 2023. URL: [https://www.inaturalist.org/observations?d1=2022-06-26&d2=2023-06-26&place\\_id=any&user\\_id=aubreymoore&verifiable=any](https://www.inaturalist.org/observations?d1=2022-06-26&d2=2023-06-26&place_id=any&user_id=aubreymoore&verifiable=any).

## ECA-PA2 Detection and Documentation of Invasive Species

**Description** Invasive insects are arriving on Guam at a very high rate (estimates range as high as one new species per day). Very few of these are detected and even fewer are identified because Guam suffers from [the taxonomic impediment](#). Even when reliable species determinations are made, new island records are only rarely documented in the scientific press. Thus, impacts of invasive insects on Guam and elsewhere in Micronesia are grossly underestimated. One of my professional goals is to work towards solving this problem by increasing the detection rate, getting specimens identified by qualified taxonomists, and publishing new island records in the scientific literature.

**Activities** iNaturalist was used to document new records for insects detected in Guam and other Micronesian Islands [1]. Three new island records for insects on Guam were documented in iNaturalist posts during the reporting period [2, 3, 4].

## References

- [1] Aubrey Moore. *Search for new island records documented in iNaturalist between June 26 2022 and June 26 2023 by Aubrey Moore*. 2022. URL: [https://www.inaturalist.org/observations?created\\_d1=2022-06-26&d2=2023-06-26&place\\_id=any&q=new&user\\_id=aubreymoore&verifiable=any](https://www.inaturalist.org/observations?created_d1=2022-06-26&d2=2023-06-26&place_id=any&q=new&user_id=aubreymoore&verifiable=any).
- [2] Aubrey Moore. *First island record for citrus blackfly, *Aleurocanthus woglumi*, attacking citrus on Guam*. May 22, 2023. URL: <https://www.inaturalist.org/observations/151875058>.
- [3] Aubrey Moore. *First island record for a parasitoid of a citrus blackfly parasitoid, *Encarsia noyesi*, on Guam*. May 10, 2023. URL: <https://www.inaturalist.org/observations/166497214>.
- [4] Aubrey Moore. *First island record for a nitidulid, *Conotelus mexicanus*, attacking *Serianthes nelsonii* on Guam*. June 17, 2023. URL: <https://www.inaturalist.org/observations/167958655>.

## ECA-PA3 University of Guam Insect Collection

**Description** The UOG insect collection is a valuable reference collection for extension entomology, teaching and research. I am a member of the board of directors for the collection and I work with Dr. Ross Miller to curate and catalog this collection.

In 2018 I ported the digital catalog for the UOG Insect Collection from a CSIRO BioLink database to a more modern web-based Symbiota database which is publicly available online [1]. I also established an internship to train entomology students how to curate an institutional insect collection and how to add specimen images to the digital catalog[2]. However, this work came to a halt because of space limitations.

Facilities provided for the UOG insect collection are very poor. The collection is literally *moth balled* in a small storage room which is too small for essential equipment such as microscopes and cameras. Curation and digitization necessitates removing specimens from the collection and transporting them outdoors to a lab where there is working space and equipment.

**Activities** In 2022, I arranged for EPSCOR funding to have a door installed between the UOG insect collection and the adjacent ANR lab. Access to bench space in the lab will partially solve the space limitation problem described in the preceding section. During 2023, moth balls were added to all specimen drawers. As a result of Typhoon Mwar, the collection was without air conditioning for about three weeks.

## References

- [1] Aubrey Moore. *SCAN University of Guam Insect Collection Collection Profile*. 2023. URL: <http://scan-bugs.org/portal/collections/misc/collprofiles.php?collid=180> (visited on 07/08/2023).
- [2] Aubrey Moore. *Internship: University of Guam Insect Collection Technician*. 2018. URL: <https://github.com/aubreymoore/Miscellaneous-Docs-for-CFES2018/raw/master/internship.pdf>.

## ECA-PA4 Mitigation of Damage to Guam's Ecosystems by Invasive Species

Guam's ecosystems are rapidly being degraded by invasive species. These include:

- **Brown treesnake** which has extirpated Guam's forest birds, causing loss of ecosystem services they provided, such as seed dispersal, insect control and pollination.
- **Cycad aulacaspis scale insect**, ACS, which has killed more than 90% of Guam's endemic cycads, known locally as *fadang*. Fadang went from being the most abundant plant in Guam's forests in 2002 to being listed as an endangered species in 2015.
- **Coconut rhinoceros beetle**, CRB, which is killing coconut palms and palma brava throughout the island. These two palm species were the second and third most abundant trees in Guam's forest in 2002.

Clearly, ecological disasters are happening on Guam, especially in forest ecosystems. As an extension entomologist, I am tasked with providing solutions to problems caused by insect pests. Unfortunately, there are no known methods for effectively controlling CAS and CRB on Guam. Therefore, I spend much of my time and effort performing applied research in an attempt to adequately control CAS and CRB so that restoration of Guam's forests can be attempted.

**Activities** A new program entitled *Plant Protection and Biosecurity for Guam and Micronesia* was submitted to the National Institute of Food and Agriculture. This program has been approved but not yet funded [1].

Applied research is reported in the Creative/Research/Scholarly in a section for CRB and a section for CAS.

## References

- [1] National Institute of Food and Agriculture. "Plant Protection and Biosecurity for Guam and Micronesia". 2023-06-27. URL: <https://github.com/aubreymoore/POW/blob/main/docs/USDA-NIFA-2022-07-31.pdf>.

## ECA-PA5 National Plant Diagnostic Network (NPDN)

**Description** I served as the UOG Coordinator for the National Plant Diagnostic Network (NPDN). UOG receives about \$15K per year from NPDN as a subrecipient of the Western Plant Diagnostic Network administered by UC Davis.

### Activities

- Participated in monthly conference calls.
- Prepared and submitted annual reports.
- Prepared a [four-year work plan and budget for FY2023-FY2026](#).
- Made a presentation entitled *The Invasive Species Problem on Guam* [1] at the 2022 WPDN annual meeting (via Zoom).
- In June 2023, I resigned as WPDN coordinator. I am currently working with the new WPDN coordinator, Jesse Bamba, to ensure a smooth transition.

### References

- [1] Aubrey Moore. “The Invasive Species Problem on Guam”. Western Plant Diagnostics Network Annual Meeting. Davis, California, Apr. 2022. URL: <https://aubreymoore.github.io/WPDN2022/>.

## ECA-PA6 Guam Invasive Species Advisory Committee (GISAC) and Guam Invasive Species Council (GISC)

I am a founding member and regular participant in GISAC. President Underwood delegated me to represent UOG as a voting member of GISC and President Krise reconfirmed my delegation.

**Activities** I participate in GISAC and GISC meetings. Unfortunately, there have been none during the current reporting period.

A GISC meeting was scheduled at Adelup on May 24, 2023. However, this was the day that Typhoon Mawar visited Guam. This GISC meeting has been postponed with a date yet to be set. I prepared a report on invasive species activities at the University of Guam [1].

### References

- [1] Aubrey Moore. *Report for the Guam Invasive Species Council Meeting, Adelup, Guam*. May 24, 2023. URL: <https://github.com/aubreymoore/GISC2023/raw/main/gisc2023.pdf>.



## ECA-PA7 Public Outreach: Internet

Since the 1990s, I have built and maintained web sites to facilitate sharing information about insects in Micronesia. I created a wiki site to serve as an index to web resources I have developed (Available at <https://guaminsects.net/aubwiki2020>). I will continue to use web sites to facilitate sharing information on Guam's insects.

## ECA-PA8 Public Outreach: Presentations

I helped to organize a meeting of the Guam Native Plant Society which was held at the UOG ALS Teaching Lab (ALS124) on Saturday, January 21, and I gave a presentation at this meeting (REF). The topic of this meeting was *Guam insects associated with Glochidion* [1].

On Saturday, April 15, 2023, I made a presentation as part of a workshop on growing hot peppers on Guam [2].

### References

- [1] Aubrey Moore. *GitHub repository: Guam insect associates of Glochidion*. 2023. URL: <https://github.com/aubreymoore/Guam-insect-associates-of-Glochidion>.
- [2] Aubrey Moore. "Interesting Facts about Chili Pepper". University of Guam. Apr. 15, 2023. URL: <https://aubreymoore.github.io/pika/>.

## ECA-PA9 Public Outreach: Miscellaneous

On March 30 2023 I participated in a 4H workshop for military children by making presentations on local insects.

## ECA-PA10 Public Outreach: Public GitHub Repositories

I attempt to provide access to as much of my work as possible using public GitHub repositories. GitHub is a free service for backing up and sharing documents on the web. Repositories which I have created or updated during the reporting period are listed in Table 1. The document you are reading, all previous versions, and related data are stored in a public GitHub directory at <https://github.com/aubreymoore/CFES2020-22>. The document can be read online or downloaded as a PDF from <https://github.com/aubreymoore/CFES2020-22/blob/main/CFES2021-06-15to2022-06-14.pdf>

I also use GitHub pages for serving static websites. A couple of good example sites are one which I created for my [ALBI345 General Entomology](#) course and one which is a [List of Insects and Mites Attacking Crops in Micronesia](#).

I will continue to create and maintain public GitHub repositories to provide access to my work as [open science](#).

Table 1: List of GitHub repositories created or pushed between 2022-06-26 and 2023-06-26. This list was generated by [code/repo-list-generator.ipynb](#).

n	repository
1	<a href="#">2020-DOI-CRB-Biocontrol</a>
2	<a href="#">2020-FS-CRB-biocontrol-project</a>
3	<a href="#">albi345-slides</a>
4	<a href="#">aleurocanthus</a>
5	<a href="#">bamba</a>
6	<a href="#">CRB-FIDL</a>
7	<a href="#">crb-flight-test</a>
8	<a href="#">crb-mex</a>
9	<a href="#">crb-mexico</a>
10	<a href="#">crb-roadside-code</a>
11	<a href="#">crb-symbiont</a>
12	<a href="#">crb-vdc</a>
13	<a href="#">crb-yona-tiff</a>
14	<a href="#">crbdist</a>
15	<a href="#">CRBG-action-group-webinar-20201209</a>
16	<a href="#">crbmex</a>
17	<a href="#">crbmexico</a>
18	<a href="#">crop-pest-list</a>
19	<a href="#">data-mining-insects-of-guam</a>
20	<a href="#">detection-range</a>
21	<a href="#">GISC2023</a>
22	<a href="#">globalbioticinteractions.github.io</a>
23	<a href="#">GloBI-test</a>
24	<a href="#">Guam-biodiversity-inventory-2023</a>
25	<a href="#">Guam-CRB-Damage-Map-20021-09</a>
26	<a href="#">Guam-CRB-Damage-Map-2021-08</a>
27	<a href="#">Guam-CRB-Damage-Map-2022-02</a>
28	<a href="#">Guam-CRB-Damage-Map-2022-11</a>
29	<a href="#">Guam-CRB-Damage-Map-2023-04</a>
30	<a href="#">Guam-CRB-web-maps</a>
31	<a href="#">Guam-Forestry-Workshop-2022</a>
32	<a href="#">guam-ias-bolo</a>
33	<a href="#">Guam-insect-associates-of-Glochidion</a>
34	<a href="#">Harmonic-Radar</a>
35	<a href="#">interaction</a>
Continued on next page	

Table 1: List of GitHub repositories created or pushed between 2022-06-26 and 2023-06-26. This list was generated by [code/repo-list-generator.ipynb](#).

n	repository
36	<a href="#">IREC</a>
37	<a href="#">McIntire-Stennis</a>
38	<a href="#">mexico1</a>
39	<a href="#">OccuTree</a>
40	<a href="#">palau-guts-experiment</a>
41	<a href="#">PESC-OIA-overview</a>
42	<a href="#">pika</a>
43	<a href="#">POW</a>
44	<a href="#">py4web</a>
45	<a href="#">rethinking-OrNV-bioassays</a>
46	<a href="#">sticky-trap-imaging</a>
47	<a href="#">TinianTrip2022</a>
48	<a href="#">young-tekken-award</a>

## Part II. Creative/Scholarly Activities or Research (CSR) 34%

### NIFA Classification

#### Critical Issues (CI)

- Sustained Agricultural Production Systems
- Plant Pest Efforts & Protect Resources of Guam

#### NIFA Science Emphasis Areas (SEA)

- **Sustainable Agricultural Production Systems** Addresses human interaction between science, technology, and agriculture. Integrates the biological, physical, and environmental and socioeconomic factors essential to successful production enterprises and viable rural communities.

#### NIFA Knowledge Areas (KA)

- KA 203 – Plant Biological Efficiency and Abiotic Stresses Affecting
- KA 211 – Insects, Mites and Other Anthropods Affecting Plants
- KA 215 – Biological Control of Pests Affecting Plants
- KA 216 – Integrated Pest Management Systems
- KA 901 - Project, and Program Design, and Statistics
- KA 902 - Administration of Projects and Programs

#### Planned Activities (PA)

- PA1 Peer Reviewed Publications (N=4)
- PA2 Publications Submitted for Peer Review (N=1)
- PA3 Journal Articles in Preparation (N=4)
- PA4 Coconut Rhinoceros Beetle (CRB) Biocontrol
- PA5 Guam Biodiversity Inventory
- PA6 Cycad Aulacaspis Scale (CAS) Biocontrol
- PA7 Eight Spot Butterfly (ESB) Conservation

## CSR-PA1 Peer Reviewed Publications (N=4)

- [1] Ronald D. Cave, Aubrey Moore, and Mark G. Wright. “Biological Control of the Cycad Aulacaspis Scale, *Aulacaspis yasumatsui*”. In: *Contributions of Classical Biological Control to U.S. Food Security, Forestry, and Biodiversity*. 2022. URL: [https://github.com/aubreymoore/CAS/raw/main/CAS\\_Biocontrol.pdf](https://github.com/aubreymoore/CAS/raw/main/CAS_Biocontrol.pdf).
- [2] Aubrey Moore and Matthew Siderhurst. “Proposal for Detecting Coconut Rhinoceros Beetle Breeding Sites Using Harmonic Radar”. In: *Research Ideas and Outcomes* 8 (Oct. 27, 2022), e86422. ISSN: 2367-7163. DOI: [10.3897/rio.8.e86422](https://doi.org/10.3897/rio.8.e86422). URL: <https://riojournal.com/article/86422/> (visited on 01/03/2023).
- [3] Jovic Aaron S. Caasi, Alex Leon Guerrero, Kangsan Yoon, Leslie J. Camacho Aquino, Aubrey Moore, Hyunju Oh, Jan Rychtář, and Dewey Taylor. “A Mathematical Model of Invasion and Control of Coconut Rhinoceros Beetle *Oryctes Rhinoceros* (L.) in Guam”. In: *Journal of Theoretical Biology* (May 18, 2023), p. 111525. ISSN: 0022-5193. DOI: [10.1016/j.jtbi.2023.111525](https://doi.org/10.1016/j.jtbi.2023.111525). URL: <https://www.sciencedirect.com/science/article/pii/S0022519323001212> (visited on 05/18/2023).
- [4] Aubrey Moore, Trevor Jackson, Roland Quitugua, Robert Bevacqua, Jonae Sayama, and Ross Miller. *Coconut Rhinoceros Beetle. US Forest Service, Forest Insect and Disease Leaflet 191*. Apr. 2023. URL: <https://www.fs.usda.gov/foresthealth/docs/fidls/FIDL-191-CoconutRhinocerosBeetle.pdf>.

## CSR-PA2 Publication submitted for Peer Review (N=1)

- [1] Sulav Paudel, Trevor Jackson, Sarah Mansfield, Mark Ero, and Aubrey Moore. “Use of pheromones for monitoring and control strategies of coconut rhinoceros beetle (*Oryctes rhinoceros*): A review”. In: (2023).

## CSR-PA3 Journal Articles in Preparation (n=5)

- [1] Aubrey Moore, N-Y Su, and Leonard Sigrah. “First Record of the Coconut Termite, *Neotermes Rainbowi* (Isoptera: Kalotermeae) from Micronesia”. In: (In Preparation).
- [2] Aubrey Moore. *The Mariana Eight Spot Butterfly, *Hypolimnas Octocula Marianensis**.
- [3] Aubrey Moore. “Three New Island Records for Bark Beetles (Curculionidae: Scolitinae) on Guam from a Single Coffee Berry Borer Trap”. In: (In Preparation).
- [4] Aubrey Moore. *Change Analysis of Guam Forest Inventory Data*.
- [5] Aubrey Moore. *Coconut Rhinoceros Beetle Invasion History*. IN PREPARATION.

## CSR-PA4 Coconut Rhinoceros Beetle (CRB) Biocontrol and Related Activity

**Description** A newly discovered biotype of coconut rhinoceros beetle (CRB-G) is rapidly killing coconuts and other palms on Guam and on other Pacific islands. Following a failed eradication attempt on Guam, CRB-G proved hard to control because it is resistant to *Oryctes rhinoceros* nudivirus (OrNV), which was previously used as the preferred biological control agent for control of CRB outbreaks on Pacific Islands and elsewhere. Prior to the discovery of CRB-G, all OrNV releases on Pacific Islands resulted in immediate and sustained suppression of CRB damage to low levels and prevented tree mortality.

Guam is currently experiencing an uncontrolled and unmonitored island-wide CRB-G outbreak which was triggered by abundant CRB-G breeding sites in the form of dead and dying vegetation left in the wake of Typhoon Dolphin which occurred in May 2015. Most of these breeding sites are inaccessible to sanitation efforts, being either deep in the jungle or on military land (which covers one third of Guam). A positive feedback cycle has begun whereby large numbers of adult beetles are killing large numbers of palms which become breeding sites which generate even higher numbers of adults. Severe damage to Guam's palms prompted the Governor of Guam to declared a state of emergency in July 2017.

The main objective of this project is to stop the uncontrolled outbreak on Guam. Entomologists working on the CRB-G problem on several Pacific islands agree that the most feasible tactic to halt tree mortality and suppress damage to tolerable levels is establishment of biological control using an isolate of OrNV which is highly effective as a biological control agent for CRB-G. We are working with collaborators to identify populations of CRB-G throughout the Asia-Pacific region. We will sample these populations for biological control agent candidates which will be evaluated in laboratory bioassays performed at UOG. Promising candidates will be field released using autodissemination as per a USDA-APHIS import and release permit.

Concurrent with establishment of CRB-G biocontrol, success of the project will be monitored in a quarterly, island-wide tree health survey and incidence of OrNV infection will be monitored in a subsample of all field collected CRB-G.

If the Guam CRB-G infestation cannot be controlled, it is expected that most palms on the island will be killed and CRB-G will continue to spread to other islands and beyond. If CRB-G invades smaller islands and atolls where coconut is the tree of life, a human tragedy will ensue. On larger islands, coconut and oil palm industries will be severely impacted. Attempts to organize a well-funded, coordinated regional project in response to CRB-G have failed underway. However, UOG plays a major role in the *ad hoc* CRB-G Action Group which was established to facilitate sharing scientific/technical information among people working on the CRB-G problem.

**Funding and Project Management** This is my largest and most important project, requiring a lot of time and effort for project management including preparation of grant pro-

posals and reports. During the reporting period, funding was provided by 2 grants totaling \$361,234: OIA-CRB, FS-CRB and FS-CRB-HR. Details, including links to project proposals, work plans and progress reports are available in the grants section of this report.

**Staffing** Grant funding for this project supports 2 full-time technicians, Christian Cayanan and Laura Caser, and two part-time technicians, Leah Bukurou and Ed Bayson.

**CRB-G biocontrol** CRB biocontrol research is focused on finding isolates of *Oryctes rhinoceros* nudivirus (OrNV) which can be used as effective biological control agents for the CRB biotype on Guam. To date, an effective virus isolate has not been found, but a screening program using lab bioassays continues.

During the first part of 2023 we tested OrNV isolates from Palau. The first bioassay tested OrNV delivered in CRB gut tissue provided by Dr. Chris Kitalong of the Palau Community College. And the second bioassay tested purified by Dr. Madoka Nakai of the Tokyo University of Agriculture and Technology. In both cases we observed no significant responses in terms of mortality, feeding activity, flight activity, or reduction in reproductive potential [1], [2], [3], [4]. Work on both bioassays was done with the assistance of Mayuho Yamauchi, a PhD candidate from Dr. Nakai's lab who visited UOG for one month [5].

Bioassays of purified OrNV isolates from the Philippines provided by AgResearch New Zealand are currently being performed.

**Establishment of a CRB Rearing Facility and Rearing Protocol** Development of biocontrol for CRB-G will require laboratory bioassays using standardized, healthy lab-reared beetles of equivalent age. Previously, we used beetles collected from pheromone traps for this purpose. However, mortality in experimental control groups was highly variable, yielding irreproducible results.

During the reporting period:

- We built and equipped a CRB rearing facility in a 40 foot shipping container.
- We developed and tested a natural larval diet by grinding dead standing coconut stems containing CRB breeding sites.
- A recent experiment shows that the growth rate of CRB larvae is greatly increased by adding field-collected larval frass to neonate larvae [6]. We suspect that this increase in growth rate is due to addition of gut symbionts present in the frass.

**Establishment of an Island-wide CRB Damage Monitoring System** We developed an island-wide roadside monitoring system to track spatial and temporal changes in CRB damage levels. Data are collected using a smart phone attached to a project vehicle. The phone continually records georeferenced roadside images as the vehicle is driven along all major roads in both directions. Data are automatically analysed by an image analysis

system which detects coconut palms in the images, calculates a damage index for each palm, and outputs results on a map of Guam. A nontechnical overview of this system was published in the 2020 WPTRC Impact Report [7].

To date, we have completed eight island-wide surveys and data for a ninth survey were recorded in June 2023 but have not yet been analyzed. Interactive damage maps and data are available on the web:

- Survey completed 2020-10-22: [View map](#) | [View GitHub repository](#) | [Download database](#)
- Survey completed 2020-12-24: [View map](#) | [View GitHub repository](#) | [Download database](#)
- Survey completed 2021-03-18: [View map](#) | [View GitHub repository](#) | [Download database](#)
- Survey completed 2021-05-20: [View map](#) | [View GitHub repository](#) | [Download database](#)
- Survey completed 2021-09-03: [View map](#) | [View GitHub repository](#) | [Download database](#)
- Survey completed 2022-02-23: [View map](#) | [View GitHub repository](#) | [Download database](#)
- Survey completed 2022-11-28: [View map](#) | [View GitHub repository](#) | [Download database](#)
- Survey completed 2023-04-07: [View map](#) | [View GitHub repository](#) | [Download database](#)

Results of surveys are made available to the Guam public via press releases [8]. Survey results show that one in five (20%) of Guam’s coconut palms growing along roadsides are damaged by CRB (Fig. 1).



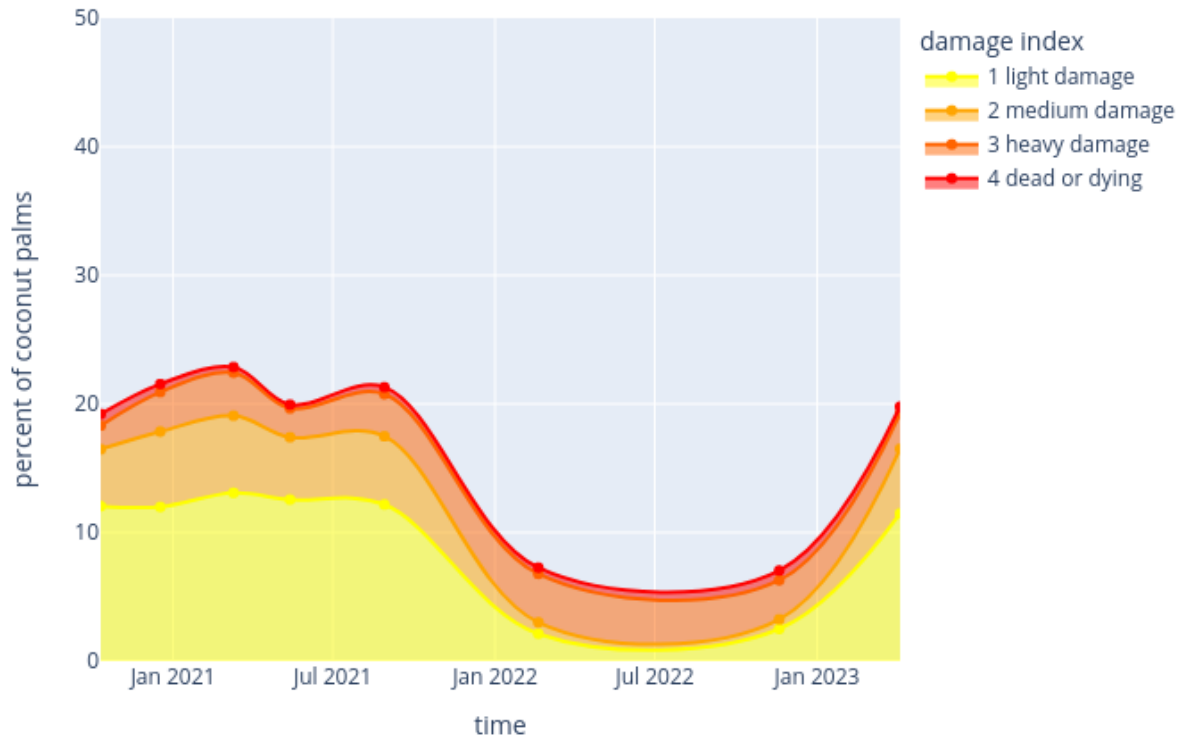


Figure 1: Percent of coconut palms growing along Guam’s roadsides which show visible damage from coconut rhinoceros beetle.

**International collaboration** will be essential for finding a way to halt massive ecological and economic damage to Pacific islands invaded by CRB-G. A **CRB-G Action Group** was formed to facilitate collaboration and cooperation. prior to COVID, this group met annually at international scientific meetings. During COVID, I helped to keep the group together by hosting Zoom webinars with assistance from the UOG Office of Information Technology. I created web pages to facilitate access recordings of these webinars:

- December 9, 2020 [9]
- March 17, 2021 [10]
- November 23, 2021 [11]

The first **Pacific Ecological Security Conference** (PESC) held in Palau during October 2022, brought together island leaders, development partners, regional organizations, agricultural/food security and natural resource managers, and the media to discuss the importance of managing and preventing the spread of invasive species in Pacific Island environments [12].

Conference hosts and sponsors included Government of Palau Ministry of Agriculture, Fisheries, and Environment, Secretariat of the Pacific Community (SPC), the East-West Center, the Global Environment Facility (GEF), the Nature Conservancy, the US Department of the Interior - Office of Insular Affairs, the U.S. Forest Service, and the Ocean Policy Research Institute.

Delegates from Guam were Roland Quitugua and Aubrey Moore from UOG and Glenn Dulla and Andrea Blas from the Department of Agriculture. The Guam delegation participated in a satellite meeting organized by the U.S. Department of the Interior - Office of Insular Affairs and the U.S. Forest Service. At this meeting each island group presented a status report on invasive species issue (See [13] for slides from the Guam presentation). This was followed by discussions on federal funding and collaboration.

**Strategic Action Plan for Coconut Rhinoceros Beetle (CRB).** Prior to the PESC, members of the Guam delegation worked with colleagues throughout the Pacific to write a Pacific-wide strategic action plan for response to the recent spread of CRB. This plan was accepted by PESC delegates and has been published online [14].

The plan includes five objectives:

1. Enhance Regional Coordination and support of PICTs to achieve the objectives of the CRB Strategic Action Plan (SAP)
2. Conduct immediate and long-term collaborative research to develop tools and understanding necessary to enable effective CRB prevention, control, and eradication
3. Prevent the spread of CRB to new locations in the Pacific region and beyond
4. Implement an active early detection, and rapid response system for new outbreaks at regional and island levels
5. Improve implementation of control efforts and mitigate the impacts of CRB where already present in the region

**Outreach** In an effort to facilitate sharing technical and scientific information among people working on CRB, I have developed and maintain several online resources including a wiki [15], a Facebook site [16], an online interactive map of CRB invasion history [17] and a CRB reference library [18], and an online email discussion site [19].

To share information about coconut rhinoceros beetle with the general public on Guam and elsewhere in Micronesia I initiate and participate in writing press releases and I also interact with reporters. Examples of recent stories published by the local media include:

- **UOG-developed rhino beetle traps win Guam golf course an innovative conservation award**, anonymous, CNAS-UOG 2022-11-29 [20]
- **Entomologist reveals origins of rhino beetle in Marianas**, by Thomas Manglona, KUAM 2023-03-03 [21]
- **UOG, Tokyo University test a rhino beetle virus from Palau on Guam’s beetles**, press release by Jackie Hanson, CNAS-UOG 2023-05-04 [5]
- **UOG, partners studying virus to curb invasive beetle population** by Richelle Aguon, Guam Daily Post 2023-05-29 [22]

**Harmonic radar** I investigated the feasibility of using harmonic radar to detect CRB breeding sites. Funding was provided by a US Forest Service grant (FS-CRB-HR). The ideas behind this research are available in a preprint [23] and an article published in the peer-reviewed *Research Ideas and Outcomes* journal [24]. Work was being done with my long-time collaborator, Dr. Matt Siderhurst, a chemical ecologist at Eastern Mennonite University, Virginia. During July 2023, Dr. Siderhurst and two of his students, Skylar List and Theodore Yoder, traveled to Guam to perform a feasibility test. We constructed harmonic radar tags by attaching antennae to diodes using conductive silver paint and glue. These tags were then and glued onto pronota of CRB adults. Sixty-four out of 101 tagged beetles flew out of containers set up at 2 field sites. Unfortunately, we were not able to detect any of these beetles during ground-based searches using harmonic radar detectors (see the FS-CRB-HR final report [25] and the project’s GitHub repository ([26])).

Examination of 36 beetles which failed to fly showed that most (22 of them) had antennae wires which had detached from diodes. We think that conductive silver paint and glue may not be strong enough for attachment of nitinol antenna wires to tags intended for CRB because these large beetles are very energetic and their movements cause breakage. We are currently attempting to solve this problem by attaching antenna wires to diodes using a special solder and flux combination design specifically for nitinol wire. We are very lucky that Michael Jordan of the US Forest Service who is stationed on Guam has very specialized skills in soldering miniature electronic components.

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## CSR-PA5 Guam Biodiversity Inventory

**Description** A biodiversity inventory is essentially a database containing a comprehensive check list of all taxa known occur within a defined area.

A terrestrial biodiversity inventory for Guam is needed to document rapid changes to Guam's ecosystems, to provide free and open access to information on Guam's flora and fauna, and to share Guam biodiversity information with the global scientific community, policy makers and the public.

The Guam Biodiversity Inventory facilitates automatic generation and updates to lists such as: a list of all invasive species on Guam with year first recorded, a list of new species described from specimens collected on Guam, a list of observations for Guam's endangered species, a list of Guam's native plants with associated herbivores and pathogens, and a list of crops grown on Guam and pests and pathogens which attack them.

Instead of building, maintaining and hosting a custom online database for the Guam Terrestrial Biodiversity Inventory, I decided to use Global Biodiversity Information Facility (GBIF) as the online database and then build a set of custom tools to access Guam specific data. This design simplified the work tremendously. The major task for the project was to automate importation of Guam data into GBIF. Development of taxonomic data standards, especially the Darwin Core Archive data format, have made it relatively easy to develop automated workflows for sharing biodiversity data among different systems. I developed methods to automate pushing Guam data from biological collections, scientific literature and iNaturalist to GBIF.

The most challenging task was datamining legacy scientific literature. I was able to datamine all 38 chapters of *Insects of Guam* and push all occurrence records to GBIF (see paragraph below on datamining). For details on the entire project, please see the final report [1] and two GitHub repositories [2]and [3].

**Funding** This project was supported by my McIntire-Stennis grant which terminated on 2022-09-30.

**Staffing** I offered an internship to work on this project to Annette Kang, a graduate student from Guam currently working on a PhD in Entomology at Cornell University. Progress on this project was impeded because of a nine month delay in processing my intern's stipend payment.

**Data mining** During the reporting period, the focus within this project was to extract data from legacy entomological literature for Guam, namely *Insects of Guam* I and II. This work was facilitated using a sophisticated workflow developed by Plazi, a Swiss-based international non-profit association supporting and promoting the development of persistent and openly accessible digital biodiversity information. The Plazi office in Brazil kindly supported this project by provided online training sessions for myself and Annette. Data extracted from

the literature are automatically published on the Global Biodiversity Information Facility as datasets and occurrence records. I wrote an [online dashboard to track our data-mining progress](#). More details are available in my 2021 annual report for this project [4]

**Harvesting Guam data from GBIF** Here are a couple of simple examples which demonstrate how to harvest Guam data from GBIF. To see an interactive check list of all taxa which occur on Guam, [click here](#). For a check list of Guam insects, [click here](#). Generating these lists is relatively simple. I published Python code for this in a public GitHub repository called OccuTree [5].

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## CSR-PA6 Cycad Aulacaspis Scale (CAS) Biocontrol

**Description** A US Forest Service survey published in 2002 reported that the most abundant tree in Guam’s forests (DBH > 5 inches) was Guam’s endemic cycad, *Cycas micronesica*. In 2003, an invasive scale insect, *Aulacaspis yasumatsui*, was detected on ornamental cycads but it soon infested wild cycads and started killing them. Within a decade, 90% of Guam’s endemic cycads have been killed by the scale and other invasive species. *Cycas micronesica* was placed on the US National Endangered Species List in 2015.

Mature plants are protected by a lady beetle I introduced, but no natural reproduction of the cycads is occurring because seeds and seedlings are still being killed by the scale insect. A likely solution to this problem is establishment of a small biocontrol agent, such as a miniature parasitic wasp, which will control scale insects infesting seeds and seedlings.

**Activities** I collaborated with Dr. Jim McConnell on insect pests impacting cycads on Tinian and Guam. During October 2022, I was requested to join the Guam Plant Extinction Prevention Program staff on a visit to Tinian to determine if any biological control agents were present in the conservation plots infested by cycad scale. None were found. For details, please see my report [1].

I set up a pest monitoring of cycads in conservation plots on Tinian using leaf samples [2] and yellow sticky traps [3].

In March 2022, I hosted a visit from Dr. Ron Cave from the University of Florida. Ron is an expert on CAS biocontrol and I have been trying to get him out here on a consulting trip for several years. Some discussions with USFWS earlier this year led to them funding the trip.

During his trip, Ron and I hosted a Zoom seminar on CAS biocontrol. I put recordings of the presentations and discussion online [4]. After the trip, Dr. Cave provided [comprehensive consulting report complete with recommendations](#).

In addition, I coauthored a book chapter on CAS biocontrol with Ron Cave and Mark Wright, University of Hawaii [5].

## References

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## CSR-PA7 Eight Spot Butterfly (ESB) Conservation

**Description** The Guam Department of Agriculture Division of Aquatic and Wildlife Resources (GDOA-DAWR) requested assistance with conservation of the rare Mariana eight-



spot butterfly, *Hypolimnas octocula marianensis*. I prepared a grant proposal and a permit application to do this work under a cooperative agreement with the GDOA-DAWR.

The objective of this project is to investigate the feasibility of captive rearing.

**Activities** I partnered with Dr. Curt (George) Fiedler, Biology Department, and Matthew Putnam, a master's student working for the Center for Island Sustainability to collaborate on this project.

A large field cage (20x20X10 feet) was built in the UOG Center for Island Sustainability compound in Dean's Circle and a shade house has been stocked with *Procris* host plants which I provided.

This project conclusively proved the feasibility of captive rearing of eight-spot butterflies. Over three hundred eggs were laid on host plant leaves by the a single adult female paired with two males in a 6'x6'x6' rearing cage. For details, please see the [final report for this project written by Dr. Curt Fiedler](#).

## Part II. University and Community Service (UCS) 15%

### UCS-PA2 Graduate Instruction

I am a graduate faculty member of the Environmental Science program and I serve on master's program committees for 3 students:

- Caylin McCormick, a student studying brown tree snake
- Ajalyn Omelau, a student studying little fire ant
- Matt Putnam, a biology student working on captive breeding of the Marianas eight-spot butterfly

### UCS-PA3 Faculty Committees

**Faculty Building Facilities Committee for the ALS** This committee was formed by the Agriculture and Life Sciences Division to consult with the Dean on facilities problems within the Agriculture and Life Sciences Building. I was re-elected as chair of this committee, joined by Dr. Jim McConnell.

**Search Committee: Restoration Ecologist** I served on a search committee for the new Restoration Ecologist position in the Biology department with Dr. Dan Lidstrom (Chair) and Dr. Frank Camacho.

**Search Committee: Research Associates for RCUOG Brown Treesnake Grants** I was a member of several search committees for BTS technicians. I was joined by Dr. Shane Siers (PI and Chair) and Dr. Dan Lindstrom.

**Continuing employment committee** I served as chair of the continuing employment committee for Jesse Bamba.

## Grants which were active during the reporting period (n=7; \$494,446)

During the reporting period, I managed 7 grants totalling \$494,446 (see Table 2 and Fig. ). Four of these grants expired during the period. Final reports were submitted and accepted. The Western Plant Diagnostic Network grants (WPDN2 and WPDN3) have recently been transferred to Jesse Bamba as the new UOG coordinator for this ongoing project. Two grants funding my CRB work remain active, DOI-OIA and FS-CRB. I will submit final reports for these grants before I retire.

Table 2: List of grants active during the reporting period (2022-06-26 through 2023-06-26).

code	title	funding
OIA-CRB ()	Establishment of Self-sustaining Biological Control of Coconut Rhinoceros Beetle Bio-type G in Micronesia	\$239,994
FS-CRB ()	Establishment of Self-sustaining Biological Control of Coconut Rhinoceros Beetle Bio-type G in Micronesia	\$98,240
BIODIVERSITY ()	Guam Forest Biodiversity Inventory	\$80,000
8SPOT ()	Captive Breeding of Eight-spot Butterfly	\$23,212
FS-CRB-HR ()	Improving Coconut Rhinoceros Beetle Breeding Site Detection Using Harmonic Radar	\$23,000
WPDN2 ()	Western Plant Diagnostic Network FY2022	\$15,000
WPDN3 ()	Western Plant Diagnostic Network FY2022	\$15,000

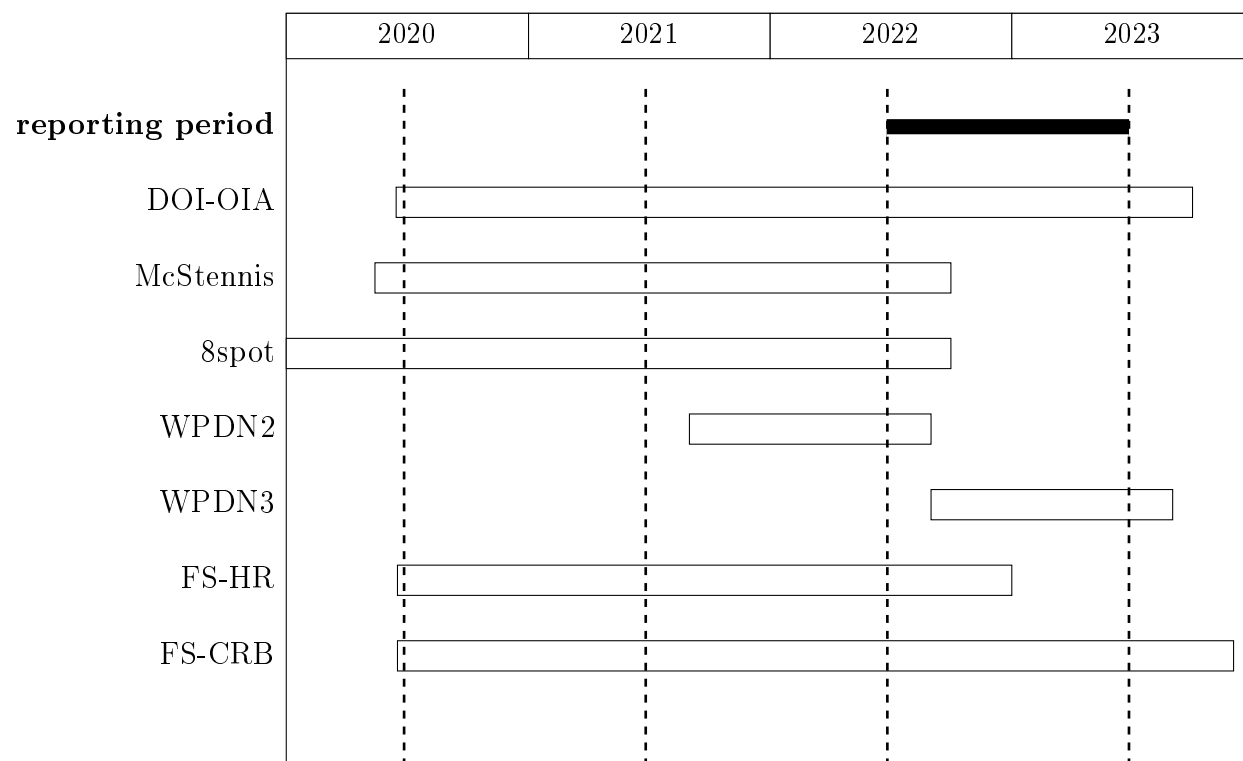


Figure 2: Performance periods for grants which were active during the reporting period (2022-06-26 through 2023-06-26).

## OIA-CRB Biological Control of Coconut Rhinoceros Beetle Biotype-G in Micronesia \$240K

### Key data

- **Code:** OIA-CRB
- **Title:** Establishment of Self-sustaining Biological Control of Coconut Rhinoceros Beetle Biotype G in Micronesia
- **Start date:** 2020-05-14
- **End date:** 2023-09-30
- **Total budget:** \$239,994
- **Federal ID:** D20AP00060
- **UOG ID:** DOI Biocontrol CRB
- **UOG Account:** 30-2F-311150
- [GitHub repository](#)

### Documents

- [Proposal](#)
- [Award letter](#)
- [Reporting requirements](#)
- [Report 1](#)

## BIODIVERSITY Guam Forest Biodiversity Inventory \$80K

### Key data

- **Code:** BIODIVERSITY
- **Title:** Guam Forest Biodiversity Inventory
- **Funding source:** McIntire-Stennis (administered by CNAS)
- **Reporting system:** [REReport](#)
- **Start date:** 2018-10-15
- **End date:** 2022-09-30
- **Total budget:** \$16,000 per year for each of 4 years
- **Federal ID:** GUA0930
- **UOG ID:**
- **UOG Account:**
- [GitHub repository](#)

### Documents

- [2018-06-21 Proposal](#)
- [2018-10-08 Project initiation](#)
- [2020-01-02 2019 Annual report](#)
- [2020-12-28 2020 Annual report](#)
- [2021-12-18 2021 Annual report](#)
- Final report due 2022-12-31.

## 8SPOT Eight Spot Butterfly Conservation \$20K

### Key data

- **Code:** 8SPOT
- **Title:** Captive Breeding of Eight-spot Butterfly
- **Start date:** 2013-10-01
- **End date:** 2022-09-30
- **Total budget:** \$23,212
- **Funding Agency:** DOI-FWS (via GDOA-DAWR)
- **Federal ID (FAIN):** F13AF01300
- **UOG ID:**
- **UOG Account:** 30-1F-315058-R
- [GitHub repository](#)

### Documents

- [Award letter \(includes scope of work and budget\)](#)
- [Updated Award Letter](#)

## WPDN2 Western Plant Diagnostic Network FY2022 \$15K

### Key data

- **Code:** WPDN2
- **Title:** Western Plant Diagnostic Network FY2022
- **Start date:** 2021-09-01
- **End date:** 2022-08-31
- **Total budget:** \$15,000
- **UOG ID:** WPTRC-UCDAVIS/USDA WPLANTDI
- **UOG Account:** 61-1F-243432
- [GitHub repository](#)

### Documents

- [Work plan and budget](#)
- [Award letter](#)
- [UOG account setup](#)



## WPDN3 Western Plant Diagnostic Network FY2022 \$15K

### Key data

- **Code:** WPDN3
- **Title:** Western Plant Diagnostic Network FY2023
- **Start date:** 2022-09-01
- **End date:** 2023-08-31
- **Total budget:** \$15,000
- **UOG ID:** WPTRC-UCDAVIS/USDA WPLANTDI
- **UOG Account:**
- [GitHub repository](#)

## FS-CRB-HR Harmonic Radar \$23K

### Key data

- **Code:** FS-CRB-HR
- **Long title:** Improving Coconut Rhinoceros Beetle Breeding Site Detection Using Harmonic Radar
- **Start date:** 2020-06-17
- **End date:** 2022-12-31
- **Total budget:** \$23,000
- **Federal ID:** 20-DG-11052021-227
- **UOG ID:** CNAS-USDA-CRB Harmonic Radar
- **UG Account:** 30-2F-311144-R
- [GitHub repository](#)

### Documents

- [Proposal](#)
- [Award letter](#)
- [Extension until 2022-12-31](#)
- [Report 1 \(2021-01-31\)](#)
- [Report 2 \(2021-07-31\)](#)
- [Final report \(90 days after expiration date\)](#)

## FS-CRB CRB Biocontrol \$98K

### Key data

- **Code:** FS-CRB
- **Long title:** Establishment of Self-sustaining Biological Control of Coconut Rhinoceros Beetle Biotype G in Micronesia
- **Start date:** 2020-06-17
- **End date:** 2022-12-31
- **Total budget:** \$98,240
- **Federal ID:** 20-DG-11052021-229
- **UOG ID:** CNAS-USDA Control of CRB
- **UG Account:** 30-2F-311143-R
- [GitHub repository](#)

### Documents

- [Proposal](#)
- [Award letter](#)
- [Extension until 2022-12-31](#)
- [Report 1 \(2021-01-31\)](#)
- [Report 2 \(2021-07-31\)](#)
- [Final report](#)
- [2021-06-15 Amended agreement](#)

## Part IV: Work Plan for June 26, 2023 - October 1, 2023

I plan to complete the following tasks prior to retiring on October 1, 2023.

1. Complete bioassays of *Oryctes rhinoceros* nudivirus from the Philippines.
2. Write and submit semiannual report for OIA-CRB grant (deadline July 31, 2023).
3. Write and submit a final report for OIA-CRB grant (deadline December 31, 2023).
4. Write and submit a final report for FS-CRB grant (deadline March 31, 2024).
5. Clean up UOG workspaces: office in ALS105, lab in ALS316, workshop in ALS116, CRB rearing lab in shipping container, insect collection room.
6. Complete UOG and GovGuam retirement requirements.
7. Apply for UOG emeritus status.
8. Participate in graduate student committees.