Remote Sensing for Detection and Monitoring of Coconut Rhinoceros Beetle Damage

Prepared by Aubrey Moore PhD, University of Guam (retired)

January 3, 2024

Contents

Note to reader: Paragraphs in italics will be removed when the preproposal is complete.

PRE-PROPOSAL LENGTH AND FORMAT: Pre-proposals shall be no longer than five (5) pages, type face not less than 11-point, and margins not less than one inch on all sides.

Proposal Number: *Generated by SEMS when proposal details are entered and saved in the system.*

Proposal Title: Remote Sensing for Detection and Monitoring of Coconut Rhinoceros Beetle Damage

Lead Principal Investigator: Roland Quitugua

Lead Organization: University of Guam, College of Natural and Applied Sciences, Mangilao, Guam

1. Objective

The proposed objectives and how the project is responsive to the objectives articulated in the SON.

Our objective is to develop an automated remote sensing system that detects, quantifies and monitors coconut rhinoceros beetle (CRB) damage on isolated Pacific islands using artificial intelligence (AI) to scan georeferenced digital images. This system will use images acquired from several sources, including roadside surveys, aerial drone surveys and the worldwide web.

This proposal addresses the statement of need (SON) entitled *Advancing Non-Indigenous Invasive Species Surveillance, Mitigation, or Biosecurity Measures Affecting Military Readiness in the Indo-Pacific Region*. The objective of this SON "is to solicit proposals that develop and mature the science to detect, survey, mitigate, characterize impacts, and minimize the establishment or spread of invasive species in the Indo-Pacific region".

Our goal is to provide a flexible toolkit of standardized, cost-effective CRB surveillance methods which can be used on any Pacific island for CRB surveillance to provide early detection, delimitation of new populations, and routine monitoring as part of eradication and control programs. Early detection and early initiation of eradication and control programs are essential for minimizing establishment or spread of CRB in the Indo-Pacific region.

2. Background

Sufficient technical background to demonstrate a thorough understanding of the problem and frame the proposed research in the context of the current state of the science or technology.

Coconut rhinoceros beetle (CRB), *Oryctes rhinoceros*, is one of the most problematic invasive species in the Indo-Pacific region. This beetle is endemic to tropical Asia (including South East Asia). CRB damages both coconut and oil palm, and is capable of killing palms when adults bore into crowns to feed on sap [6, 5]. For general information on CRB and response guidelines for Pacific islands invaded by this pest please see [9, 14, 15].

2.1. Invasion history of CRB in the Pacific

CRB was inadvertently introduced into the Pacific in 1909 when infested rubber tree plants were transported to Samoa from Sri Lanka (previously known as Ceylon) [11]. The pest rapidly multiplied in Samoa and subsequently spread to several nearby Polynesian islands. Separate invasions further distributed CRB through Palau, parts of Papua New Guinea, and other Pacific nations through disruptions and uncontrolled movements during World War II [11, 12]. The invasive phase of the beetle was brought under control by the discovery and distribution of a viral biocontrol agent, *Oryctes rhinoceros* nudivirus (OrNV). OrNV is currently present and causes persistent population suppression on many of the CRB infested Pacific Islands [5, 10]. Virus introduction into affected Pacific Island countries and territories suppressed and weakened the CRB populations such that its spread into the Pacific islands ceased and for 30 years there was no further range expansion of CRB [13].

However, the situation changed. Since the beginning of in 2007, CRB has invaded six islands north of the equator (Table 1) and six islands south of the equator (Table 2). Most of these populations are resistant to biological control using OrNV [7]. There is an urgent need to develop cost-efficient, standardized survey methods for early detection, delimitation, and mapping levels of CRB damage on Pacific islands which have been invaded or at a risk of being invaded.

DOD has permanent installations on four of the six islands north of the equator which have recently been invaded by CRB (Table 1). Establishment of CRB on Majuro Atoll in 2023 increases risk of CRB invasion on the neighboring Kwajelein Atoll on which DOD operates the Ronald Reagan Ballistic Missile Defense Test Site (RTS). Commercial and military flights from Hawaii, Majuro and Guam regularly land at the Bucholz Army Airfield which is part of RTS.

Table 1: Recent CRB invasions of Pacific islands north of the equator.

Year	Island
2007	Guam
2013	Oahu, Hawaii
2017	Rota, Commonwealth of the Northern Mariana Islands
2023	Majuro, Republic of the Marshall Islands
2023	Kauaii, Hawaii
2023	Hawaii (Big Island), Hawaii

Table 2: Recent CRB invasions of Pacific islands south of the equator.

Year	Island
2015	Guadalcanal, Solomon Islands
2015	Port Moresby area, Papua New Guinea
2017	Savo, Solomon Islands
2017	Malaita, Solomon Islands
2019	Vanuatu
2019	New Caledonia

2.2. CRB damage survey methods

CRB populations can be detected and monitored by observing the damage they cause. V-shaped cuts to palm fronds (Fig. 1) and other symptoms of CRB adult feeding activity are highly distinctive and are visible from up to a few hundred meters. A review of CRB damage survey methods is provided by Mansfield et al. 2023 [4]. Originally, surveyors recorded direct visual observations but recent surveys almost always use georeferenced digital images. Severity of damage to palms in these images is later classified by human experts using a standardized 3-level scale (undamaged, damaged, dead) or a 5-level scale (undamaged, low damage, medium damage, high damage, dead). Results are then displayed on maps.

2.2.1. Automation of CRB damage surveys

On Guam, CRB damage surveys have been automated in three ways:

1. Images are not taken by a human, but are recorded by a smart phone camera mounted on a vehicle at a rate of one per second (Fig. 3). GPS coordinates are also recorded by the smart phone;

2. Coconut palms in each image are located, assigned a damage level, and are scanned for v-shaped cuts by AI object detectors;

3. Location of coconut palms and damage levels are automatically added to an interactive web map (Fig. 5).

This allows us to complete a damage survey of Guam within the few hours it takes to drive all the major roads on the island in both directions.

Automated damage surveys will facilitate detection and monitoring of CRB populations. Our methods may be used as an alternative to or in conjunction with other surveillance methods including pheromone trapping [1] and E-DNA sampling currently being developed by a SERDP project [8]. We estimate annual cost of $7,700 for automated damage surveys on Guam compared to $81,140 for pheromone trapping (Fig. 4). We do not have cost estimates for E-DNA surveys.

2.2.2. Previous work on automated CRB damage surveys

The proposed project builds on an existing system which maps CRB damage using automated analysis of ground-based imagery acquired by a smart phone mounted on a road vehicle for data acquisition (Fig. 3). Currently, images are taken at a rate of one per second by a free cell phone app named OpenCamera. Each image is 1920 x 1080 pixels in size and GPS coordinates are embedded within the image file. Note that the phone does not require a SIM card or internet connection during data acquisition.

After transferring image files to a laptop computer, each is examined by a pair of object detectors trained by an artificial intelligence technique called deep learning. One detector puts a bounding box around all coconut palms within each image and assigns a standardized 5-scale damage index to each palm. The damage index is based on a standard methodology developed by CRB experts working on islands in the south Pacific [4]. A second object detector counts v-shaped cuts to coconut palm in fronds which are distinctive signs of CRB feeding damage. Results from Guam surveys are visualized using interactive web maps (Fig. 5). This ground-based system has been used for routine roadside surveys on Guam and has also been used for early detection of CRB damage on Rota in the Commonwealth of the Northern Mariana Islands and on Majuro in the Republic of the Marshall Islands (Fig. 6).

We will improve the existing ground-based system and adapt this system to use aerial drone imagery to facilitate:

- CRB damage detection over large areas of remote, otherwise inaccessible, terrain
- early detection and delimiting surveys in rapid response projects on islands where CRB has not yet established, increasing chances of eradication
- monitoring temporal and spatial changes in CRB damage on islands where CRB has established
- measuring changes in CRB damage in response to biological control, sanitation, and other mitigation tactics

2.2.3. Images of CRB damage on the world-wide-web

Images of coconut palms with probable CRB damage are publicly available on the world-wide-web. Some of these are the result of citizen science projects initiated specifically to detect CRB damage, such as an iNaturalist project entitled *FA 15 UOG CRB Damage Survey* and a Project Noah mission entitled *Help Save Hawaii's Coconut Trees*.

In addition, there are many unlabeled images of coconut palms available as incidental images within social media and elsewhere on the world-wide-web and new images are being added daily. Paudel and Jackson have been tracking potential biosecurity incursions using publicly available images on the web [3] and have discovered strong evidence that CRB has invaded Mexico [2].

We intend to apply our object detectors to automate searches for CRB damage in publicly available images on the web.

3. Approach

The technical approach and methods, preferably structured in hypothesis-driven tasks that clearly identify how the objectives of the proposed project will be addressed. This section should be the primary focus of the pre-proposal.

Design features. All code will be developed using free open-source software (FOSS) and all code, data and documentation generated by the project will be made available via public GitHub repositories. Methods will be designed to be appropriate for use on Pacific islands which have limited technical and financial resources.

Object detectors. Existing object detectors, which have been used in roadside CRB damage surveys on Guam since 2020, will be retrained to minimize false positives and false negatives. Performance before and after retraining will be evaluated using standard metrics and reported in a technical report. A user manual for the object detectors will be provided.

Roadside surveys. Improved object detectors will be tested in ongoing quarterly CRB damage surveys on Guam using methods detailed above. Combined roadside and drone surveys will be performed on Majuro.

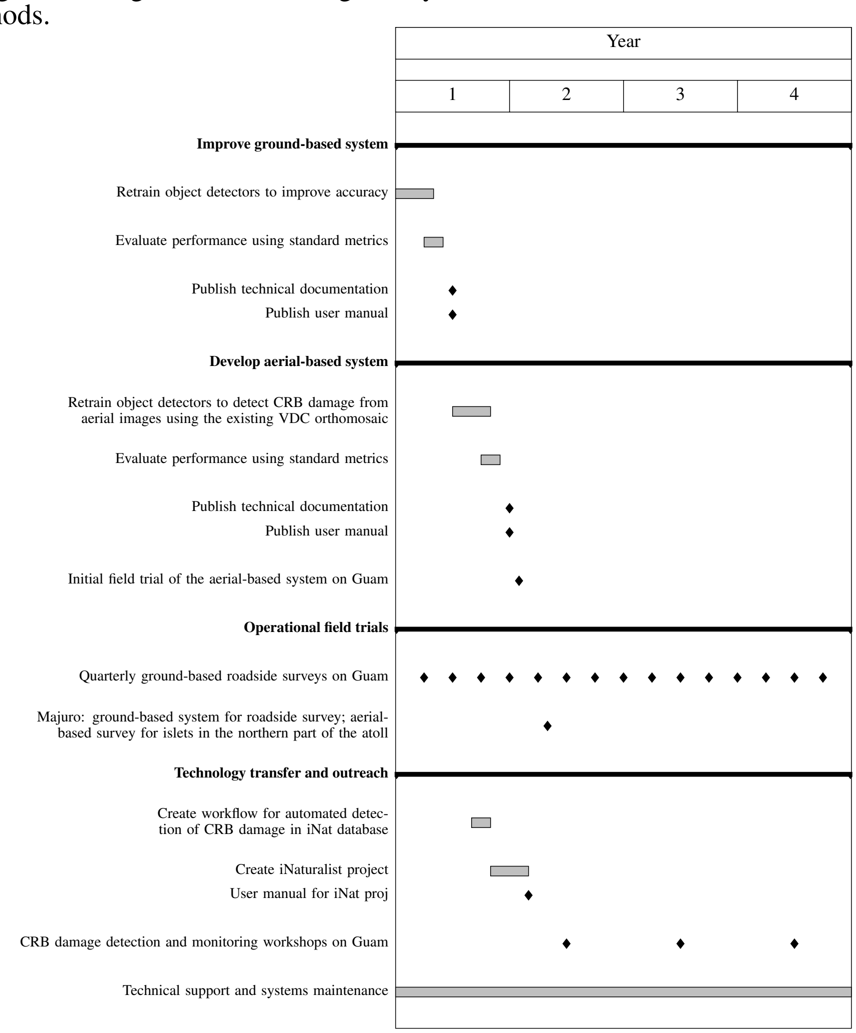
Aerial drone surveys. Object detectors will be retrained to detect CRB from the air. A high quality dataset of drone imagery acquired on Guam specifically for this purpose is available in a public GitHub repository at `https://github.com/aubreymoore/crb-vdc`. An initial field trial of the drone survey methodology will be conducted on Guam. Technical documentation and a user guide for the aerial drone survey methodology will be written. Operational testing be performed on Majuro.

World wide web surveys. Our object detectors can process images acquired from any source, including world-wide-web. In an automated scan of iNaturalist observations from Mexico, our v-shaped cut detector found coconut palms with CRB damage symptoms (Fig. 2), corroborating evidence of a CRB population in Mexico from manual searches of social media images by Jackson and Paudel [2]. We will develop automatic workflows which scan the web continually scan the web to detect images of coconut palms with CRB feeding damage symptoms. We will establish a CRB damage project on iNaturalist which can be used by *citizen scientists* to help detect CRB. Images uploaded to this project will be automatically scanned by our object detectors and alerts will be sent back to the observer when detections are made.

Technology transfer After the first year of the project, we will offer training workshops on CRB damage monitoring at the University of Guam. We will also provide a virtual help desk to provide technical support to islands interested in establishing CRB damage surveys.

4. Schedule

The duration of this project component will be 4 years. The first half of the project will focus on developing, evaluating and documenting survey methods and the second half will focus on field field trials of the methods.



5. Cost

The estimated total costs, including labor, materials, travel, burdens, and profit (fixed fee, if any, for eligible organizations) by year. A detailed breakout of costs is not required or desired in the pre-proposal.

Table 3: Estimated costs. An administrative fee, charged by the Research Corporation of the University of Guam, is 20% of the total grant.

Year	**Island**
Labor	$300,000
Materials	$200,000
Travel	$200,000
Administration fee	$175,000
Total	**$875,000**

6. Research Team

Identify the Principal Investigator(s), the key co-performers, and their respective organizations. If multiple co-performers are proposed, indicate their responsibilities within the project.

The members of the research team for this project component and their roles are listed in Table 4.

Table 4: Research team and roles.

Research team members	**Roles**
Roland Quitugua (PI), University of Guam	Project management
Dr. Aubrey Moore, University of Guam (retired)	Systems design, coding, analysis and mapping
Dr. Romina King, University of Guam	Aerial drone imagery and GIS
Dr. Ken Puliafico, Center for Environmental Management of Military Lands, Colorado State University	Liaison with DOD and CRB damage surveys on DOD lands in Guam.
Dr. Mark Ero, Secretariat of the Pacific Community, Fiji	
Dr. Sulav Paudel, AgResearch New Zealand	
Dr. Sean Marshall, AgResearch, New Zeland, Fiji	

Table 5: List of additional collaborators, not directly funded by this project. TO BE POPULATED.

Collaborator(s)	**Roles**
Name(s) and affiliation	Roles

A. Abbreviated Curriculum Vitae

Required: One (1) page each for the Principal Investigator and other significant performers involved with the project that provide relevant research experience. Include the full mailing addresses, phone numbers, and email addresses for each person listed.

A.1. Roland Quitugua

COMING SOON

A.2. Dr. Aubrey Moore

Purok 4, Lunga, Valencia
Negros Oriental 6215
Philippines

aubreymoore2013@gmail.com

Aubrey Moore

Education

1988	Ph.D., Entomology, University of Hawaii, Honolulu, Hawaii
1984	M.S., Entomology, Michigan State University, East Lansing, Michigan
1979	B.Sc., Integrated Science Studies, Carleton University, Ottawa, Ontario

Professional Experience

2008-2023	Extension Entomologist, Cooperative Extension Service, University of Guam, Guam
2003-2008	Research Associate, College of Natural & Applied Sciences, University of Guam, Guam
1999-2003	Pesticide Evaluator, Pest Management Regulatory Agency, Health Canada, Ottawa, ON
1998-1999	Entomologist, School of Agriculture & Life Sciences, Northern Marianas College, Saipan

Relevant Publications

[1] Moore, Aubrey. 2019. **YouTube Video: Training an Object Detector to Locate Coconut Palms Damaged or Killed by Coconut Rhinoceros Beetle.** https://www.youtube.com/watch?v=zzSorqcmt9U

[2] Moore, Aubrey, and Trevor Jackson. 2020. **Automated Roadside Video Surveys for Detecting and Monitoring Coconut Rhinoceros Beetle Damage to Coconut Palms.** Presented at the Annual Meeting of the CRB-G Action Group. https://aubreymoore.github.io/crb-roadside-slides

[3] Moore, Aubrey. 2020. **Using a Cell Phone and Artificial Intelligence to Map Coconut Rhinoceros Beetle Damage.** WPTRC Impact Report. Mangilao, Guam: Western Pacific Tropical Research Center, College of Natural and Applied Sciences, University of Guam. https://www.uog.edu/_resources/files/wptrc/2020WPTRCFinal.pdf

[4] Moore, Aubrey. 2023. **Webmaps showing results of automated roadside surveys of coconut rhinoceros beetle damage on Guam.** https://aubreymoore.github.io/Guam-CRB-web-maps/

[5] Moore, Aubrey. 2023. **Webmap showing results of an automated roadside survey on Majuro** https://aubreymoore.github.io/Majuro-CRB-damage-map-1/webmap

[6] Moore, Aubrey, Trevor Jackson, Roland Quitugua, Robert Bevacqua, Jonae Sayama, and Ross Miller. 2023. **Coconut Rhinoceros Beetle. US Forest Service, Forest Insect and Disease Leaflet 191.** https://www.fs.usda.gov/foresthealth/docs/fidls/FIDL-191-CoconutRhinocerosBeetle.pdf.

A.3. Dr. Romina King

COMING SOON

A.4. Dr. Kenneth Puliafico - to be updated

Kenneth Puliafico, Ph.D.
Entomologist
Center for Environmental Management of Military Lands
PO Box 3226, Hagatna GU 96932
671-929-7510
ken.puliafico@colostate.edu

Doctor of Philosophy, Entomology (2008)
Plant Soils & Entomological Science, University of Idaho. Moscow, ID 83843.
Master of Science, Entomology (2003)
Entomology Department, Montana State University. Bozeman, MT 59717
Bachelor of Science, Biological Science, with honors (1992)
Biology Department, Montana State University. Bozeman, MT 59717

2018 – present **Supervisory Entomologist –Center for Environmental Management of Military Lands, Colorado State University, based in Asan, Guam, USA**

- Organized monitoring program for Coconut Rhinoceros Beetle (CRB) populations and assessed damage across Andersen Air Force Base and Naval Base Guam
- Supervised baseline and long term monitoring for terrestrial arthropods for improved biosecurity in transport networks and training areas
- Implemented treatment program for invasive Little Fire Ants on military lands
- Scientific and taxonomic support of vehicle and cargo inspections for military exercises in Guam, Commonwealth of the Northern Marianas and partner nations

2018 **Research Entomologist –** Research Corporation of the University of Hawaii, Pacific Cooperative Studies Unit UH-Manoa, Institute of Pacific Islands Forestry, Hilo, Hawaii
2017 –2018 **Volunteer Research Entomologist –** USDA Forest Service, Institute of Pacific Islands Forestry, Pacific Southwest Research Station, Hilo, Hawaii
2012 – 2017 **Research Entomologist – Postdoctoral Researcher –** USDA Forest Service, Institute of Pacific Islands Forestry, Pacific Southwest Research Station, Volcano, Hawaii
2010 – 2012 **Research Associate: Entomology –** Natural History Museum of Denmark, Zoological Museum, Copenhagen, Denmark
2010 **Contract Entomologist –**Landcare Research – Biosystematics Team, Auckland, New Zealand
2009 – 2010 **Volunteer Curator –** Entomology Auckland War Memorial Museum, Entomology Department, Auckland, New Zealand
2009 **Entomologist –** Montana Department of Agriculture – Pest Management Bureau, Helena, MT, USA
1994 – 1996 **U.S. Peace Corps Volunteer** – National University of Samoa, Apia, Samoa

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Publications and Presentations available on request

A.5. Dr. Mark Ero

COMING SOON

A.6. Dr. Sulav Paudel

COMING SOON

A.7. Dr. Sean Marshall

COMING SOON

B. List of Acronyms

Required: Provide a complete list of acronyms used in your preproposal and their definitions. List the proposal number at the top of the page.

Proposal Number: *Proposal Number: Generated by the SERDP and ESTCP Management System (SEMS) when the proposal details are entered and saved in the system.*

AI Artificial intelligence

CRB Coconut rhinoceros beetle, *Oryctes rhinoceros*

E-DNA Environmental deoxyribonucleic acid

DOD United States Department of Defense

OrNV *Oryctes rhinoceros* nudivirus, a biological control agent for coconut rhinoceros beetle

SON Statement of need

RTS Ronald Reagan Ballistic Missile Defense Test Site

USDA-APHIS United States Department of Agriculture, Animal & Plant Health Inspection Service

C. Literature Citations

Required, if literature is cited: Literature Citations: Provide literature citations for any material cited in the technical section or the supporting technical data.

[1] Paudel, S., Jackson, T. A., Mansfield, S., Ero, M., Moore, A., Marshall, S. D. G. (2023). Use of pheromones for monitoring and control strategies of coconut rhinoceros beetle (Oryctes rhinoceros): A review. Crop Protection, 174, 106400. https://doi.org/10.1016/j.cropro.2023.106400

[2] Jackson TA, Rincon M, Villamizar L, Paudel S (2022). Social media posts suggest that coconut rhinoceros beetle has established in the Western Hemisphere. https://doi.org/10.22541/au.165828152.28371110/v1

[3] Paudel S, Jackson TA (2023). Tracking potential biosecurity incursions using publicly available images: A case of coconut rhinoceros beetle. Journal of Applied Entomology, 147(8), 661?666. https://doi.org/10.1111/jen.13155

[4] Mansfield S, Balanama A, van Koten C, Paudel S, Bowie M, Jackson TA, Marshall SDG (2023). Assessment of coconut palm damage caused by coconut rhinoceros beetle, *Oryctes rhinoceros* (Coleoptera: Scarabaeidae), New Zealand Journal of Crop and Horticultural Science https://doi.org/10.1080/01140671.2023.2278791

[5] Bedford, G. O.(2013). Long-term reduction in damage by rhinoceros beetle *Oryctes rhinoceros* (L.) (Coleoptera: Scarabaeidae: Dynastinae) to coconut palms at *Oryctes* nudivirus release sites on Viti Levu, Fiji. African J Agricultural Research. 8(49):6422-5.

[6] Bedford, G. O.(2013). Biology and management of palm dynastid beetles: Recent advances. Annual Review of Entomology 58: 353?372.

[7] Marshall SDG, Moore A, Vaqalo M, Noble A, Jackson TA (2017). A new haplotype of the coconut rhinoceros beetle, *Oryctes rhinoceros*, has escaped biological control by *Oryctes rhinoceros* nudivirus and is invading Pacific Islands. Journal of Invertebrate Pathology 149:127-34. 10.1016/j.jip.2017.07.006

[8] SERDP (2021) A Terrestrial Environmental DNA Survey for Coconut Rhinoceros Beetle Surveillance and Mitigation https://demo.serdp-estcp.mil/projects/details/7f27cd20-f1bc-4ae2-a46a-c8b8d0f30c11/rc21-1137-project-overview

[9] Pallipparambil G. (2015). New Pest Response Guidelines: Oryctes rhinoceros (L.) Coleoptera:Scarabaeidae Coconut Rhinoceros Beetle [Internet]. United States Department of Agriculture - Animal and Plant Health Inspection Service - Plant Protection and Quarantine; 2015 p. 180. https://github.com/aubreymoore/detectorBeetles/raw/master/Documents%20for%20paper/USDA%20APHIS%20PPQ%202015.pdf

[10] Huger AM (2005). The *Oryctes* virus: Its detection, identification, and implementation in biological control of the coconut palm rhinoceros beetle, *Oryctes rhinoceros* (Coleoptera: Scarabaeidae). Journal of Invertebrate Pathology. 89(1):78-84.

[11] Catley, A. (1969). The coconut rhinoceros beetle Oryctes rhinoceros(L). International Journal of Pest Management: Part A, 15(1), 18?30. https://doi.org/10.1080/04345546909415075

[12] Gressitt, L. J. (1953). The coconut rhinoceros beetle (Oryctes rhinoceros) with particular reference to the Palau Islands (pp. 1?83). https://books.google.com/books?id=OtcZAQAAIAAJ

[13] Vaqalo, M., Marshall, S., Jackson, T., Moore, A. (2015). SPC Pest Alert 51: An emerging biotype of coconut rhinoceros beetle discovered in the Pacific. http://westernipm.org/index.cfm/center-projects/signature-programs/invasive-species/coconut-rhinoceros-beetle/pest-alert-coconut-rhino-beetle-final-pdf/

[14] Jackson, T., Marshall, S., Mansfield, S., Atumurirava, F. (2020). Coconut rhinoceros beetle (Oryctes rhinoceros): A manual for control and management of the pest in Pacific Island countries and territories. Pacific Community. https://www.spc.int/DigitalLibrary/Doc/LRD/Reports/57498_Coconut_rhinoceros_beetle___A_manual_for_control_and_management_of_the_pest_in_Pacific_Island_countries_and_territories.pdf

[15] Moore, A., Jackson, T., Quitugua, R., Bevacqua, R., Sayama, J., Miller, R. (2023, April). Coconut Rhinoceros Beetle. US Forest Service, Forest Insect and Disease Leaflet 191. https://www.fs.usda.gov/foresthealth/docs/fidls/FIDL-191-CoconutRhinocerosBeetle.pdf

D. Supporting Technical Data

Optional: Supporting Technical Data (limited to 3 pages): Data sheets, charts, referenced research extracts.

Figure 1: Image downloaded from https://www.crbhawaii.org

Figure 2: Coconut palm in Mexico with CRB damage symptoms. This image was discovered by an automated search of web images using an object detector developed for CRB damage monitoring on Guam. Image source: https://www.inaturalist.org/observations/76810823.

WPTRC 2020 IMPACT REPORT

Everyone living on Guam has seen damage to coconut palms caused by coconut rhinoceros beetles (CRB). CRB has been on Guam since 2007, however, until recently, the number of palms being damaged and killed on Guam was unknown. Standardized surveys of CRB damage are needed to monitor changes over time and space, especially in response to control activities and for early detection of CRB in new geographic areas.

UOG entomologist Aubrey Moore has developed a highly automated method for routine island-wide monitoring of CRB damage using a cell phone and artificial intelligence (AI).

Methods for monitoring CRB damage have been developed. But these rely on direct observation or image analysis by human experts and are too time-consuming and expensive for routine monitoring over large areas.

Dr. Trevor Jackson, an entomologist working for AgResearch New Zealand, has developed a survey method based on a five-level scale for classifying CRB damage to individual coconut palms. Jackson's method is being used extensively on CRB-infested islands in the South Pacific. Moore decided to develop an island-wide roadside CRB damage survey for Guam based on an automated version of Jackson's method.

A smart phone is attached to a vehicle using a magnetic mount. As the car travels, the phone records videos that are analyzed by open-source software.

In the automated survey, a smart phone mounted on a car or truck records continuous videos while the vehicle is driven along all major roads on Guam. The smart phone uses a couple of free apps: OpenCamera records videos and GPSLogger records GPS coordinates.

Recent technical breakthroughs in AI have made it much easier to train computers to recognize objects in digital images. Moore collaborated with OnePanel Inc., an AI tech

Above: medium to severe CRB damage detected in the Royal Palms area of Dededo.

Below: each dot on the map represents a video frame in which one or more coconut palms was detected. The image at the top is a frame extract form a video with approximate at coordinates indicated by the camera icon.

Continue reading

8

Figure 3: Feature article in the University of Guam's Western Pacific Tropical Research Center impact report for 2020.

Pheromone trap monitoring (1000 traps visited biweekly)		
Pheromone traps	commercial panel traps	$24,140
Lures	oryctalure; new lures every 10 weeks	$20,800
Technician	1000 traps visited biweekly; full time @ $15 per hour	$31,200
Vehicle	maintenance and fuel	$5,000
Total		**$81,140**
Automated roadside damage monitoring (quarterly island-wide surveys)		
Smart phone	with cables and magnetic mount	$300
Technician	4 surveys; 40 h per survey; part time @ $15 per hour	$2,400
Vehicle	maintenance and fuel	$5,000
Total		**$7,700**

Figure 4: Estimated annual cost of pheromone trapping and automated roadside damage surveys for monitoring CRB on Guam.

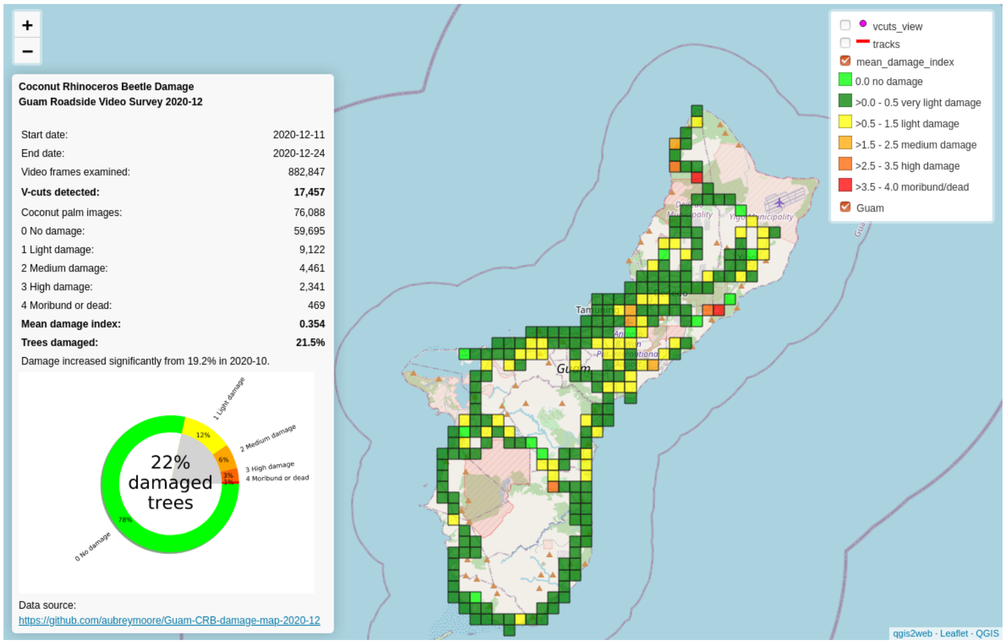

Figure 5: Screenshot of an interactive web map showing results from a roadside video survey of CRB damage on Guam in December 2020.

Figure 6: Screenshot of an interactive web map showing results of a CRB roadside survey on Majuro. 13,488 roadside images were taken during a 4 hours islandwide survey. Only 3 images contained v-shaped cuts. As indicated by the green circle, these images were in a very tight cluster located just east of the airport.

E. Existing Support

Optional: Existing Support: If the Principal Investigator is funded by other programs to conduct research that overlaps or parallels the current proposal, provide a brief description of that support (half a page per relevant effort).

COMING SOON.