Remote Sensing for Detection and Monitoring of Coconut Rhinoceros Beetle Damage

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

December 19, 2023

Contents

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

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.

The objective of our proposal is to develop automated remote sensing systems that detect, quantify and monitor coconut rhinoceros beetle (CRB) damage on isolated Pacific islands using artificial intelligence (AI) to scan georeferenced digital images from 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".

Show how the project is responsive to the objectives articulated in the SON

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 the tropical Asia region (including South East Asia). CRB damages both coconut and oil palm, and can sometimes kill palms when adults bore into crowns to feed on sap (Bedford, 2013a, 2013b). The beetle was inadvertently introduced into the Pacific in 1909 when infested rubber tree plants were transported to Samoa from Sri Lanka (previously known as Ceylon) (Catley, 1969). 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 (Catley, 1969; Gressitt, 1953). 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 (Bedford, 2013b; Huger, 2005). 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 (Secretariat of the Pacific Community, 2015).

However, the situation changed following discovery of an OrNV resistant CRB population on Guam in 2007 [Marshall et al], this pest has resumed its spread throughout the Pacific. Recently invaded islands include Guam (2007) ...

The proposed project builds on an existing system which maps CRB damage using automated analysis of ground-based imagery which uses a smart phone mounted on a road vehicle for data acquisition. 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 [REF]. The damage index is based on a standard methodology developed by CRB experts working on islands in the south Pacific [REF]. A second object detector counts v-shaped cuts to coconut palm in fronds which are distinctive signs of CRB feeding damage. Results are visualized using interactive web maps. 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 [REFS].

For details on this ground-based CRB damage survey methodology see the attached file roadside.pdf.

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

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.

- improve ground-based system
  - improve code to minimize false positive s and false negatives
  - evaluate performance using standard metrics
  - provide technical documentation
  - provide user manual
  - develop and test a cell phone app which does real-time object detection. This can be done by embedding the two object detectors in the app. This app would work in much the same way as a license plate reader: sending out an alert whenever CRB damage is detected. Images to be saved for eventual upload and further analysis. IF THIS APP IS MADE AVAILABLE PUBLICLY, IT COULD BE USED FOR CROWD SOURCED DATA SIMILAR TO INAT.
- develop aerial-based system
  - train object detectors to detect CRB damage from aerial images using the existing VDC orthomosaic
  - evaluate performance using standard metrics
  - provide technical documentation
  - provide user manual
- operational testing
  - initial operational testing of the ground-based system during routine island-wide CRB damage surveys on Guam
  - initial operational testing of the aerial-based system using new imagery from VDC
  - remote operational testing on Majuro: ground-based system for roadside survey; aerial-based survey for islets in the northern part of the atoll
  - detection survey on Kiribati using both ground-based and aerial-based methods

4. Schedule

The duration of the project, along with a milestone chart that delineates the timeline for each task and major deliverables.

The duration of this project component will be 4 years. A schedule with milestones is provided as Fig. 1.

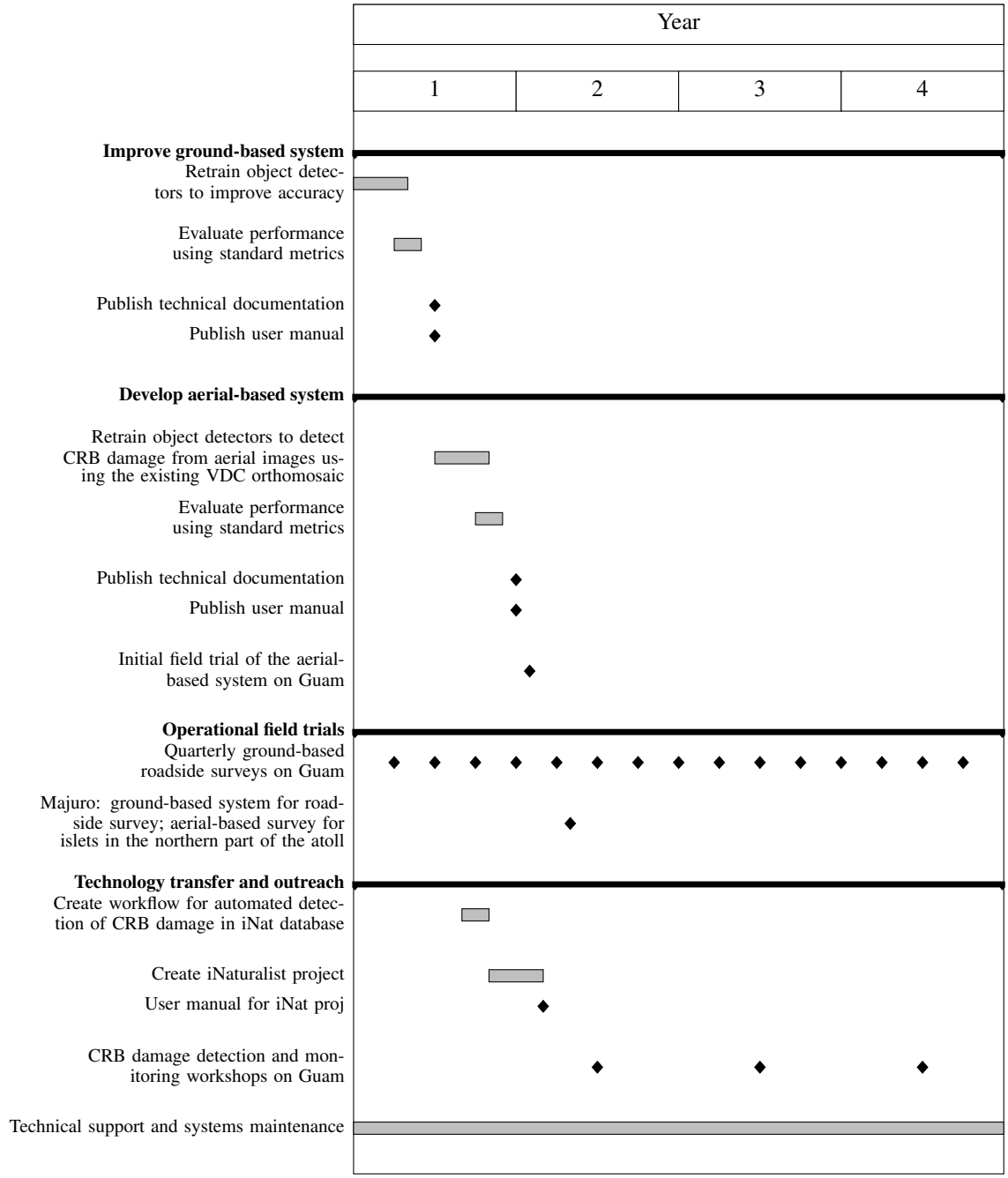

Figure 1: Project schedule.

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.

Estimated total costs for this project component are provided in Table **??**.

Table 1: Summary of project cost estimates. Indirect rates are 26% for CEMML, 27.6% for NCSU, and 15% for UOG. These rates are applied to Labor + Materials + Travel. In addition, NCSU charges 27.6% on the first $25k of each subcontract awarded to CEMML and UOG. For details see Appendix **??**.

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 2.

Table 2: 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 and coding
Dr. Romina King, University of Guam	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 3: 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

Please see next page.

Aubrey Moore Ph.D.

College of Natural and Applied Sciences, University of Guam
Rm. 105, Agriculture and Life Sciences Bldg., 303 Campus Dr., Mangilao, Guam 96923, USA
Email: aubreymoore@triton.uog.edu **Cell phone:** +1 671 686-5664

Education

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

Employment

2008-Pres.	Professor of Entomology, 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, Land Grant Program, Northern Marianas College, Saipan
1992-1997	Research Director, Land Grant Program, Northern Marianas College, Saipan
1991-1992	Entomologist, Northern Mariana Islands Department of Natural Resources, Saipan
1990-1991	Entomologist, Ag. Development in the American Pacific Project, Guam & Maui
1989-1990	Research Associate, University of Hawaii Ag. Expt. Stn., Maui, Hawaii
1988	Post-doctoral Fellow, Hawaiian Evolutionary Biology Program, Honolulu, Hawaii
19851988	Graduate Assistant, Department of Entomology, University of Hawaii, Honolulu, Hawaii
1985-1986	Programmer/consultant, University of Hawaii Computing Center, Honolulu, Hawaii
1984	Research Associate, Dept. of Entomology, Michigan State University, East Lansing, MI
1984	Entomologist, Insect and Rodent Control Sect., MI Dept. of Public Health, Lansing, MI
1981-1984	Graduate Assistant, Dept. of Entomology, Michigan State University, East Lansing, MI
1979-1981	Res. Tech., Forest Pest Management Inst., Environment Canada, Sault Ste. Marie, ON
1975-1979	Res. Tech., Chemical Control Research Institute, Environment Canada, Ottawa, ON

Relevant Publications

[1] Sean D. G. Marshall, Aubrey Moore, Maclean Vaqalo, Alasdair Noble, and Trevor A. Jackson(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, p. 127-134. http://www.sciencedirect.com/science/article/pii/S0022201117300289

[2] Aubrey Moore(2018). **The Guam Coconut Rhinoceros Beetle Problem: Past, Present and Future.** Zenodo. https://zenodo.org/record/1185371#.W4Dolh9fhhE

[3] Aubrey Moore, Roland Quitugua, Ian Iriarte, Michael Melzer, Shizu Watanabe, Zhiqiang Cheng, and Jathan Muna Barnes(2016). **Movement of Packaged Soil Products as a Dispersal Pathway for Coconut Rhinoceros Beetle, *Oryctes rhinoceros* (Coleoptera: Scarabaeidae) and Other Invasive Species.** Proceedings of the Hawaiian Entomological Society 48: pp. 21-22. http://scholarspace.manoa.hawaii.edu/handle/10125/42743

[4] Aubrey Moore, Diego C. Barahona, Katherine A. Lehman, Dominick A. Skabeikis, Ian R. Iriarte, Eric B. Jang, and Mattew S. Siderhurst(2017). **Judas Beetles: Discovering Cryptic Breeding Sites by Radio-Tracking Coconut Rhinoceros Beetles, *Oryctes rhinoceros* (Coleoptera: Scarabaeidae).** Journal of Environmental Entomology 46(1), pp. 92-99. https://doi.org/10.1093/ee/nvw152

[5] Aubrey Moore, Trevor Jackson, Roland Quitugua, Paul Bassler, and Russell Campbell(2015). **Coconut Rhinoceros Beetles (Coleoptera : Scarabaeidae) Develop in Arboreal Breeding Sites in Guam.** Florida Entomologist 98(3), pp. 1012-1014. http://journals.fcla.edu/flaent/article/download/84794/84044

[6] R W Mankin and Aubrey Moore(2010). **Acoustic Detection of *Oryctes rhinoceros* (Coleoptera: Scarabaeidae: Dynastinae) and *Nasutitermes luzonicus* (Isoptera: Termitidae) in Palm Trees in Urban Guam**. Journal of Economic Entomology 103(4) pp. 1135-1143. http://www.ingentaconnect.com/content/esa/jee/2010/00000103/00000004/art00014

Relevant Grants

USDA-APHIS Farm Bill 2013 through 2019: Biological Control of Coconut Rhinoceros Beetle
DOI, Office of Insular Affairs: 2018-2019: Funding to Hire an Insect Pathologist Post-Doc
CESU 2013 Federal Candidate Species Surveys on Guam
NAVFAC Pacific 2011 Peer Review of the Micronesia Biosecurity Plan and Development of a Strategic Implementation Plan

A.3. Dr. Romina King

COMING SOON.

A.4. Dr. Kenneth Puliafico

Please see next page.

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.*

CEMML Center for Environmental Management of Military Lands, Colorado State University

CRB Coconut rhinoceros beetle, *Oryctes rhinoceros*

CRB-G Coconut rhinoceros beetle, Guam biotype

CRB-S Coconut rhinoceros beetle, not Guam biotype

DOD United States Department of Defense

IATS Invasive, alien terrestrial species

LD50 Dose which causes 50% mortality

LT50 For a fixed dose, this is time between treatment and 50% mortality

NCSU North Carolina State University

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

SON Statement of need

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] Bedford G. O. (1986). Biological control of the rhinoceros beetle (*Oryctes rhinoceros*) in the South Pacific by baculovirus. Agriculture, Ecosystems and Environment. 15:141-7.

[2] 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.

[3] 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. http://www.sciencedirect.com/science/article/pii/S0022201117300289

[4] 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.

[5] Vander Meer RK, Ghatak UR, Alam SK, Chakraborti PC, Alam KS, Chakraborti PC (1979). (+-)-Des-N-Morphinan: a unique bridged hydrocarbon attractant for the rhinoceros beetle, *Oryctes rhinoceros*, and development of an olfactometer. Environmental Entomology. 8(1):6-10.

[6] 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.

D. Supporting Technical Data

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

COMING SOON.

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 (1?2 page per relevant effort).

COMING SOON.