Proposal for detecting coconut rhinoceros beetle breeding sites using harmonic radar

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Abstract

Coconut rhinoceros beetle (CRB), a major pest of coconut and oil palms, is causing severe economic and environmental damage following recent invasions of several Pacific islands. Population suppression and eradication of this pest requires location and destruction of active and potential breeding sites where all life stages aggregate. Three search tactics for discovering breeding sites have been used with limited success: visual search by humans, search with assistance from detector dogs and search by tracking CRB adults fitted with radio transmitters.

Here, we suggest a fourth search tactic: releasing CRB adults fitted with harmonic radar tags to locate breeding sites. Our idea is to find static end points for tags which accumulate at breeding sites, rather than active tracking of individual beetles. We plan to use commercially available hand-held harmonic radar devices. If we are successful, this technique may be useful for locating other insects which aggregate, such as hornets and other social insects.

Keywords

harmonic radar, coconut rhinoceros beetle, *Oryctes rhinoceros*

Coconut rhinoceros beetle biology

Life cycle and feeding behaviour

Oryctes rhinoceros (Linnaeus 1758) (Coleoptera, Scarabaeidae, Dynastinae), commonly known as the coconut rhinoceros beetle (CRB) is a major pest of coconut and oil palm. CRB undergo complete metamorphosis with four distinct life stages: egg, larva, pupa and adult. Larvae feed exclusively on dead and decaying vegetation and cause no economic damage. Damage is done only by adults. Both sexes bore into palm crownshafts to feed on sap to fuel their flight muscles. They typically bore through several fronds developing within the crownshaft. When these fronds emerge and expand several weeks later, large v-shaped cuts become visible, a distinctive sign of CRB damage. Palms are killed only when the apical meristem (growing tip), located at the base of the crownshaft, is damaged by boring activity. However, mortality caused by CRB is rare unless CRB population densities are high and individual palms are attacked simultaneously by multiple adults. Adults reside in crowns of live palms only briefly, exiting bore holes within a few days to aggregate at breeding sites where they mate and lay eggs. Each CRB may feed up to six times during its adult lifetime (Vander Meer and Mclean 1975), boring a new hole each time.

Gressitt (1953) estimated that 88% of a CRB population occurs in breeding site aggregations. The remaining 12% accounts for adults temporarily visiting live palm crowns to feed on sap. Breeding site aggregations occur in a wide variety of decaying plant material including dead standing coconut palms, fallen coconut logs, rotting coconut stumps, decaying wood of many tree species, piles of compost, sawdust and manure. Small breeding sites are sometimes located in live coconut palm crowns where grubs feed on accumulated detritus (Moore et al. 2015).

Severe damage by CRB is often triggered by an abundant larval food supply in the form of massive amounts of decaying vegetation generated by typhoons, large-scale land clearing and wars. CRB damage can be totally avoided if all breeding sites are located and destroyed prior to first emergence of adults at about six months after sites are established.

Location and destruction of breeding sites, usually referred to as *sanitation*, is essential for CRB population suppression leading to eradication. Sanitation is likely to suppress CRB populations much more effectively than control programmes aimed primarily at killing only adults, such as mass trapping and insecticides applied to live palms.

Eradication programmes

The recipe for eradicating coconut rhinoceros beetle from an island is simple:

- find and destroy all active and potential breeding sites
- prevent re-infestation by closing invasion pathways

However, eradication of CRB from an island has proven extremely difficult once this pest has become established. There have been many CRB eradication attempts and some are currently in progress. However, there has been only one success. This was accomplished on the tiny (36 km^2) Niuatoputapu Island (also known as Keppel Island), which lies between Samoa and Tonga (Catley 1969). During a period spanning 1922 to 1930, all CRB breeding sites were located and destroyed.

We suggest that harmonic radar may be useful for efficient detection of CRB breeding sites, thus facilitating efficient sanitation and improved probability of successful eradication. Sanitation methods for CRB breeding site material include burning, fumigation, insectide application, composting, burial and steam sterilisation (U.S. Department of Agriculture, Animal Plant Health Inspection Service, Plant Protection and Quarantine 2014).U.S. Department of Agriculture, Animal Plant Health Inspection Service, Plant Protection and Quarantine (2014)

Invasion history

CRB is endemic to the tropical Asia region (including South East Asia). 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). 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). The invasive phase of the beetle was brought under control by the discovery and distribution of a viral biocontrol agent, *Oryctes rhinoceros* nudivirus (OrNV) (Huger 2005). OrNV causes persistent population suppression on many of the CRB-infested Pacific Islands where it was introduced (Bedford 1986, Bedford 2013).

Detection of CRB on Guam in 2007 heralded a second wave of Pacific island invasions by this pest. Following a failed eradication attempt, it was discovered that the Guam beetles are apparently resistant to OrNV infection and they are being referred to as the CRB-G biotype (Marshall et al. 2017). This problematic biotype has been detected on several previously uninfested Pacific islands including Guam (2007), Papua New Guinea (2009), Hawaiian Islands (2013) and Solomon Islands (2015). CRB-G is damaging and killing coconut and oil palms on these islands and it is expected to spread further if high populations are not suppressed (Jackson 2015).

Methods for Detecting Coconut Rhinoceros Beetle Breeding Sites

Three methods have previously been used for detecting CRB breeding sites: unassisted search by humans, search with assistance from detector dogs and search with assistance from CRB adults equipped with radio transmitters. Pros and cons of these methods plus a fourth method, search with assistance from CRB adults equipped with harmonic radar tags, are presented in Table 1.

Search by humans

Unassisted visual search by humans is limited because many CRB breeding sites are cryptic with a high probability of being undetected.

Search assisted by detector dogs

Use of dogs trained to detect odours associated with CRB grubs was pioneered by the Guam Coconut Rhinoceros Eradication Program. Four teams of CRB detector dogs and handlers were deployed on Guam from July 2009 until November 2011. The idea was that visual search by handlers, coupled with olfactory search by dogs, would be most valuable towards the end of the eradication programme in the last few cryptic breeding sites. The Guam detector dogs were effective in finding breeding sites. However, maintaining detector dogs was expensive and could not be sustained with the limited funding available. CRB detector dog teams are currently deployed by the Hawaii CRB Eradication Program on the Island of Oahu.

Search assisted by beetles, equipped with radio transmitters

After discontinuation of the Guam CRB detector dog programme, we began investigating the prospect of replacing dogs with CRB adults for olfactory detection of breeding sites.

Location of mammals and birds is commonly done by attaching radio transmitters to individuals. These individuals can then be tracked using a directional antenna attached to a radio receiver. Miniaturised transmitters are now small enough to be carried by large insects and these can be tracked using receivers and antennae identical to what is used for locating mammals and birds. Our idea was to track CRB adults, equipped with miniature radio transmitters, to see if they would lead us to breeding sites.

A feasibility trial performed on Guam showed that the method worked (Moore et al. 2017). However, this method has not been used operationally because of financial and logistic limitations:

- transmitters are expensive, about $200 each
- transmitters require batteries which are not replaceable or rechargeable. These batteries are relatively heavy, have a shelf life of a few months and an operational field life of a few weeks.

Search by beetles, equipped with harmonic radar tags

To continue investigating the prospect of replacing dogs with CRB adults for olfactory detection of breeding sites, we are now considering use of harmonic radar tags which are much cheaper, lighter and longer lasting than radio transmitters. Harmonic radar (HR) has been used for locating and tracking insects for more than a quarter of a century. Mascanzoni and Wallin (1986) used HR to track carabid beetles and Riley et al. (1996) used HR to track bees.

HR can be used to locate and track tagged insects. The key to HR is a tiny tag consisting of a wire antenna and diode attached to the insect being tracked. When the tag is illuminated by a beam of fixed-frequency radio waves from an HR transceiver, the tag radiates at integer multiples of that frequency (harmonic frequencies). The HR transceiver is designed to detect harmonic frequencies and to reject the original frequency. In this way, the HR transceiver detects the harmonic frequencies radiated by the tag and rejects backscatter (reflections of the original frequency from foliage, the ground and other objects). More comprehensive descriptions of insect location and tracking using HR are presented by Mascanzoni and Wallin (1986) and O'Neal et al. (2004).

Objectives

Given the importance of finding and destroying breeding sites in order to suppress and eradicate coconut rhinoceros beetle populations and the inherent difficulty of locating cryptic breeding sites which are found in a wide range of habitats, there is a pressing need to develop cheap yet efficient detection methods to find these sites. We hope that harmonic radar will allow efficient detection of cryptic aggregation sites where tags have accumulated. We are planning a field trial on Guam to assess the feasibility of this approach. We will essentially repeat the previous trial in which we tagged CRB adults with radio transmitters (Moore et al. 2017), but this time, we will use HR tags.

Materials and Methods

HR tagged CRB will be released at two sites, War in the Pacific National Historical Park in Asan (13.4659 N, 144.7109 E) and the University of Guam Agricultural Research Station in Yigo (13.5324 N, 144.8733 E). After a period of several days, location of the tags will be determined.

We will use a hand-held harmonic radar device (RECCO AB, Lidingö, Sweden) designed for finding avalanche victims.

We will fabricate dipole harmonic radar tags by attaching antennae to Schottky diodes (RECCO AB, Lidingö, Sweden). Two 8 cm lengths of super-elastic nitinol wire (0.076 mm diameter, McMaster-Carr, Aurora, OH, USA) will be attached to the diode with UV-activated adhesive (Bondic, Niagara Falls, NY, USA), so that each wire touches one of the diode contacts while avoiding the opposite diode contact and the other wire. Electrical connections between the wires and the diode contacts will be secured using conductive silver paint (GC Electronics, Rockford, IL, USA).

As with our previous work with radio transmitters, CRB adults caught in pheromone traps will be fed banana slices in the laboratory and their flight ability will be tested prior to selection for the feasibility study. Tagged beetles will be released in the evening about one hour after sunset.

A thorough ground search of the release site neighbourhood using RECCO harmonic radar devices will start several days after release. Search paths and location of detected tags will be recorded using GPS devices.

Discussion

Development of a relatively cheap and efficient method for locating CRB breeding sites using harmonic radar will facilitate population suppression and increase the probability of eradication. This method may also be applied to other invasive species, especially those that aggregate, such as hornets and other social insects.

Searches may be highly automated by mounting an HR transceiver, equipped with a data logger on an aerial drone. The drone will fly programmed search paths close to the ground with the HR beam pointing downwards, thus compensating for the relative short detection range of the HR transceiver. At the completion of a search, a map will be compiled by merging the HR data log with search path coordinates recorded by the drone.

Conflicts of interest

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Figure 1.

CRB detector dogs and handlers deployed on Guam from July 2009 until November 2011.

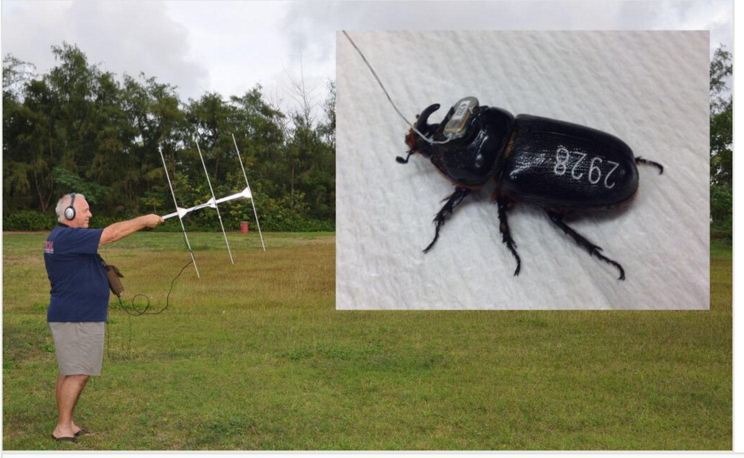

Figure 2.

Miniaturised radio transmitter tag attached to the thorax of a coconut rhinoceros beetle. A radio receiver and yagi antenna are used for locating the tag.

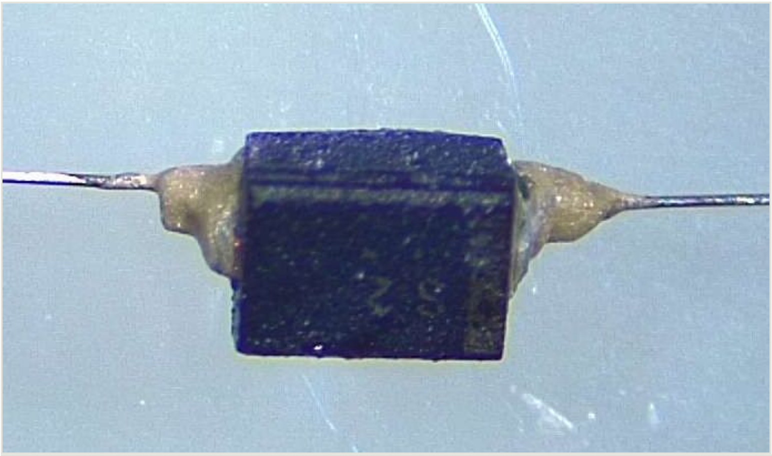

Figure 3.
Harmonic radar tag consisting of a diode with a dipole antenna. The diode is about 2 mm long.

Figure 4.

RECCO hand-held harmonic radar transceiver.

Table 1.

Pros and cons for methods used to search for *Oryctes rhinoceros* breeding sites.

Method	Pros	Cons
Humans	• Minimal training required • Both active and potential breeding sites are detected	• May be expensive (depends on labour costs)
Dogs (Fig. 1)	• Dogs can detect cryptic breeding sites which may not be obvious to human searchers.	• Arboreal breeding sites will be missed • Training, handling and upkeep is expensive • Each dog must be attended by a human handler
Beetles with radio tags (Fig. 2)	• No training required • Both ground-based and arboreal breeding sites are detected • Tags can have different frequencies	• Tags are expensive (about $200 each) • Tags have limited battery life (limited shelf life, limited field endurance) • The ATS A2414 radio transmitter we used had a relatively heavy mass of 400 mg • Releasing live beetles may be undesirable
Beetles with harmonic radar tags (Fig. 3 and Fig. 4)	• No training required • Both ground-based and arboreal breeding sites are detected • Tags are cheap, costing approximately $4 each including materials (~ $2.50) and labour for antenna attachment ($1.50 at $15 per h) • Unlimited shelf life • Unlimited field life • The diode plus antenna we plan to use as a harmonic radar tag has a mass of only 20.4 mg	• Tags do not have different frequencies (but CRB can be marked uniquely) • Releasing live beetles may be undesirable • Detection range is short: 50 to 70 m under ideal conditions (line of sight and correction orientation). Detection range under field conditions is approximately 10 m.