Coconut Rhinoceros Beetle

Aubrey Moore

August 23, 2022

Figure 1: Male coconut rhinoceros beetle head and pronotum.

Coconut rhinoceros beetle (CRB) (Fig. 1), *Oryctes rhinoceros* (L.) (Coleoptera: Scarabaeidae) is a major pest of coconut palm and oil palm. It is native to southeast Asia, but its has invaded many Pacific islands and its range is currently expanding towards the Americas.

1 Biology

1.1 Taxonomy

The coconut rhinoceros beetle (CRB), *Oryctes rhinoceros* L., is a member of the scarab beetle family, Scarabaeidae, and the subfamily Dynastinae. Taxonomic expertise is required to differentiate *O. rhinoceros* from serveral other similar *Oryctes* species, some of which also attack coconut and other palms.

1.2 Life cycle and reproduction

CRB has four life stages: eggs, grubs, pupae and adults with the grubs having three substages called instars (Fig. 2). The life span depends on environmental conditions, varying between 9 months and 18 months and generation time varies between 5 months and 9 months. The CRB sex ratio is usually close to 50:50 and females lay about 65 eggs during their lifetime. Under optimal environmental conditions with an unlimited food supply, CRB populations have the potential to grow at a rate of 3,250% per generation.

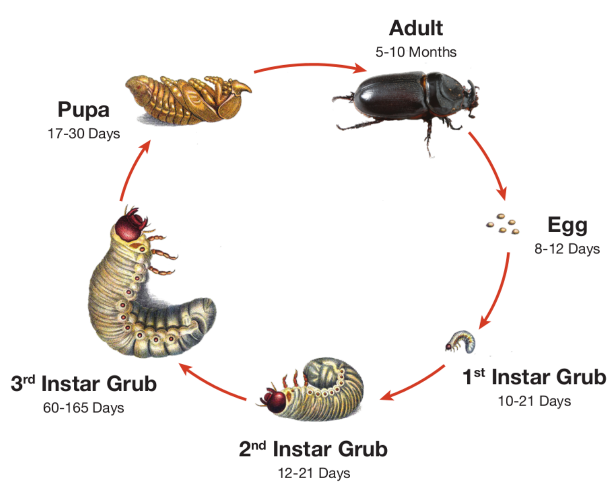

Figure 2: Coconut rhinoceros beetle life cycle.

Like all beetles, CRB has four life stages: egg, grub, pupa, and adult (Fig. 2). Only the adult stage causes damage. Grubs feed only on decaying vegetation and do no harm. Adult males and females bore into the crowns of coconut palms and other palms to feed on sap.

Adults do not feed on leaves, but they bore holes through developing leaves on their way to the white tissue at the interior of the crown. When these damaged leaves eventually emerge from the crown, they have v-shaped cuts in them, a distinctive sign of CRB damage (Fig. 3). Each adult feeds on sap for only a few days. It then leaves the crown to search for a breeding site. Palms may be killed if a CRB bores through the growing tip (the meristem). Mature palms are rarely killed at low CRB population levels. However, trees are killed when they are simultaneously attacked by many adults during a population outbreak such as the one we are currently experiencing on Guam. Coconut rhinoceros beetles attain maximum mass at the end of the third instar. Adults are at maximum mass when they have just emerged from the pupa.

All life stages aggregate in CRB breeding sites which can be found wherever vegetation accumulates. Preferred sites are standing dead coconut stems and fallen coconut logs and fronds. But piles of anything with a high concentration of decaying vegetation can be used as a breeding site including green-waste, dead trees of any species, saw dust, and manure. CRB breeding sites have even been found in commercially bagged soil purchased from a local hardware store [3].

A female CRB lays about 100 eggs during her lifetime. Assuming a 50% sex ratio and 100% survival, there will be a population increase of 5,000% during each generation. Thus population explosions may occur when abundant potential breeding sites are available in the form of rotting vegetation following destruction in the wake of a typhoon, large scale land clearing, or war. Large numbers of CRB adults generated by a population explosion may result in large numbers of palms being killed. The dead standing trunks soon become ideal breeding sites which generate even higher numbers of adults. This positive feedback loop will end when the rhino beetles run out of food, meaning when most of the palms have been killed and rotted away.

1.3 Damage caused by CRB

Grubs feed in almost any type of dead vegetation, including animal manure, and they do no damage. However, both male and female adults bore into the crowns of palms to feed on sap. Each feeding event lasts only a few days and each adult may feed several times before it dies. Damage is caused when the beetle bores through developing fronds. When these fronds emerge from the crown they exhibit distinctive v-shaped cuts. This damage results in reduced photosynthesis, fruit production and loss of aesthetic quality in ornamental palms. If a bore hole passes through the meristem (growing tip), the palm will not be able to produce new fronds and it will die within about a year when all existing fronds senesce and fall off. Mortality caused by CRB is often seen in young palms but it is rare in mature palms unless there is a high population of CRB adults.

Some host plant lists for CRB are misleading. Grubs can be found in decaying material from many plant species such as LIST HERE. Accumulation of detritus in coconut palm crowns on Guam. Dead limbs.

Adults will occasionally bore into live plants to feed on sap for a few days. Banana pandanus cycads etc.

1.4 Population dynamics

Dead palms quickly become ideal CRB breeding sites. Large numbers of dead palms killed by CRB adults or large accumulations of dead vegetation caused by tropical cyclones, massive land clearing or military activity may lead to a self-sustaining CRB outbreak: CRB adults kill palms which become breeding sites. CRB adults emerging from these breeding sites kill surrounding palms, creating new breeding sites which generate even more adults which kill even more palms. An example of this positive feedback cycle occurred in Palau as a result of massive destruction of palms and other vegetation during the Second World War. Prior to the war, CRB was very rare in Palau but shortly afterwards about 50% of coconut palms were killed by CRB.

Figure 3: Coconut palms severely attacked by coconut rhinoceros beetle.

1.5 Geographic distribution

CRB invaded islands in the Pacific and Indian Oceans during two waves of movement (Fig. 4). The first wave occurred started in 1909 when CRB was accidentally transported to from Sri Lanka to Samoa with shipment of rubber tree seedlings and it ended during the 1970s [5]. All of the CRB range expansion during this period was south of the equator except for the invasion of the Ryuku Islands (Japan) starting in 1921 [6] and invasion of the Palau Islands in about 1942 [5]. In Palau, there was a population explosion of rhino beetles because WWII activities created abundant breeding sites. This resulted in about 50% coconut palm mortality overall, and total loss of coconut palms on some of the smaller islands [7].

The second wave of CRB invasions started in 2007 with discovery of CRB on Guam, followed by invasion of Oahu (Hawaii), Port Morseby (Papua New Guinea), Guadalcanal, Savo and Malaita (Solomon Islands), and Rota (Commonwealth of the Northern Mariana Islands). Beetles in the second wave of invasions are genetically different from those in the first wave [8] and these are being referred to as the Guam biotype or CRB-G for short.

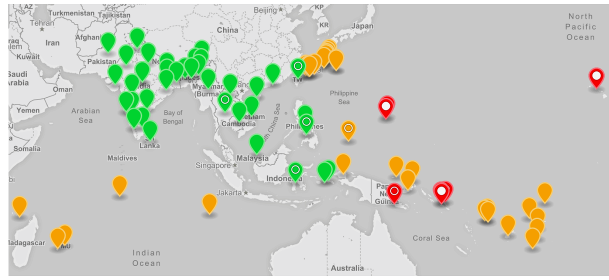

Figure 4: Screenshot of an online interactive web map [1] showing the geographic distribution of the coconut rhinoceros beetle. Green markers: native range; Orange markers: first detected during the 20th century; Red markers first detected during the 21st century; Open circle: population includes CRB-G biotype; Filled circle: population is exclusively CRB-G biotype.

2 Control actions for CRB

2.1 Eradication

In theory, eradication of CRB from a newly invaded area can be attained by blocking invasion pathways coupled with finding and destroying all breeding sites. In practice, eradication has proven to be very difficult after initial establishment of a CRB population, despite early detection and rapid response.

Only one of many eradication attempts has succeeded. This was accomplished on the tiny (36 km^2) Niuatoputapu Island (also known as Keppel Island), which lies between Samoa and Tonga. During a period spanning 1922 to 1930 all CRB breeding sites were located and destroyed.

2.2 Sanitation

Sanitation includes detection and destruction of active and potential CRB breeding sites.

Breeding site detection Local searches for breeding sites are usually initiated in response to visible damage to palms or capture of adults in pheromone traps. In Guam and Hawaii, dogs trained to sniff out CRB grubs have been deployed to assist human searchers. Recent research suggests that CRB adults fitted with miniature radio transmitters or harmonic radar tags may be a cost effective way of detecting cryptic breeding sites. The essential idea is that the radio transmitters and tags will accumulate at breeding sites where adults aggregate. They can then be detected by ground and/or aerial surveys using radio receivers or harmonic radar transceivers.

Removal of standing dead palms CRB adults are attracted to standing dead palm trees that have begun to rot from the crown. Females will lay their eggs in the rotting palm trunk and the developing larvae will feed on the decaying fibers near the top of the trunk, which starts to decompose in the center forming a protective tube for larval development. As the larvae increase in size and strength of their mandibles, they can penetrate further down the trunk leaving a column of frass and cut fibers for the early instars. Dead standing palms should be felled, cut into pieces and burnt or buried to remove potential breeding sites. In some situations, larvae may develop in the crown of live palms. This only occurs where there are large accumulations of organic matter in the frond bases. The organic matter should be removed where possible.

Disposal of dead felled palms Mature palm trees will fall after being weakened by fungal diseases (*Ganoderma*), after strong winds during tropical cyclones or after the felling of senile palms prior to replanting. Dead palms on the ground should be cut up into manageable lengths or chipped prior to disposal by burning or deep burial.

Covering of palm stumps Felled palms leave a stump which is suitable for development of larvae as it rots. In management of palm plantations in Asia, where a zero-burning policy is in operation, ground cover is planted shortly after felling to cover the debris and make it less attractive to the flying beetles. The legumes *Mucuna* spp. and *Pueraria javanica* are ground cover plants that are commonly used, as they will add nitrogen to the soil and cover the decaying trunks.

Management of organic matter and compost Heaps of organic matter, particularly palm debris, provide excellent food material for development of CRB larvae. Any deep piles of organic material will be attractive to the egg laying females. Heaps of fronds or empty fruit bunches are particularly susceptible. Sawdust from sawmills that process palm timber is also a favorable resource for beetle development. General compost, farmyard manure and even organic garbage can provide sites for development of the larvae. The first step in reducing the threat of beetles emerging from composts is management of the organic matter. Palm debris should be spread among the palms to break down rapidly and release nutrients rather than being piled in heaps. Compost or farmyard manure should be turned regularly, and larvae removed, or pigs and chickens can assist by eating exposed larvae. In urban environments, organic material is often gathered during environmental clean-up and composted, but this may provide a centre for re-infestation of the locality. Compost can be sterilized or fumigated to kill larvae; however, this process is energy-demanding and expensive. Sterile compost will also be susceptible to re-invasion. Where feasible, compost heaps can be covered with netting to trap emerging beetles.

Burning CRB breeding material is the most dependable method for removing the food source for CRB grubs. In Hawaii CRB sanitation programs, breeding site material is being burned on-site using air-curtain burners and some is being trucked to a waste-to-energy electrical power generation plant.

2.3 Trapping

CRB trapping can be used for different purposes including surveillance for early detection, monitoring growth and spread of a population over time, and for population suppression by mass trapping. In all cases, the trap needs to be attractive enough to draw in beetles from a distance strong and enough to contain them once they are captured. Olfactory and visual attractants can be used to increase trap catch.

Artificial breeding sites One of the first traps to be developed was the Hoyt trap made from a metal can set on top of a coconut trunk or wooden post. The can was capped with a length of coconut stem with a hole in the center large enough for a beetle to enter. The trap system was used extensively and functioned because it mimicked a standing, decaying coconut stem which is attractive to CRB adults. Another early trap system was simply a pile of coconut log sections placed on the ground.

FIGURE NEEDED: HOYT TRAP, LOG TRAP, PANEL TRAP

Pheromone traps Design and utility of traps changed with the discovery of ethyl chrysanthemate as an attractant. This was rapidly superseded by ethyl-4-methyloctanoate (E4-MO) commonly referred to as oryctalure, the male-produced aggregation pheromone of CRB, which could be synthesized. E4-MO attracts both sexes, has been used for more than 30 years and is produced commercially by several companies.

Pheromone traps for surveillance need to be robust, inexpensive, attractive to beetles, difficult to exit and simple to service. Bucket traps, often with vanes, have been used in surveillance trapping in Guam and Hawaii where thousands of traps have been distributed and monitored for delimitation of the spread of CRB populations and to monitor success of control activities. Bucket traps have also been used extensively for monitoring throughout the Pacific Islands and Southeast Asia. Panel traps?

NEED FIGURE OF BUCKET TRAP (VANED AND UNVANED) AND PANEL TRAP

Efficacy of pheromone traps for population suppression Trapping will remove insects from the population and can contribute to pest and damage reduction. Bucket traps baited with pheromone have been reported to reduce CRB populations in Malaysia and the related *O. monoceros* in West Africa.

It has been suggested that mass trapping can eradicated newly detected population of CRB by trapping all adults, thus preventing all reproduction and damage. Mass trapping was performed on Guam shortly after detection of CRB in the Tumon Bay hotel are in 2007. These traps did not mitigate damage to palms with the mass trapping areas. During 2010, the trap catch rate in Tumon Bay was only 0.006 beetles per trap day, but CRB damage was visible in 100% of coconut palms. In contrast, a similar mass trapping program in Samoa trapped 0.150 per trap-day, but the proportion of damaged coconut palms was 30%. Note that the Guam population is the CRB-G biotype and the Samoan population is the CRB-S biotype. Three possible explanations have been suggested to account for these observations:

1. Traps baited with oryctalure are more attractive to CRB-S than CRB-G.
2. CRB-G individuals do far more damage than CRB-S individuals.
3. At very high population levels and trap densities there is so much pheromone in the air that beetles cannot navigate to pheromone sources

but had very little effectcan be eradicated However, bucket and pipe traps are not sufficient for high-density, invasive populations.

Improving trap efficiency has been a goal of the research team at the University of Guam where a range of innovative trap designs have been developed (Moore et al. 2014; Iriate et al. 2015). Bucket trap catches have been improved by expanding the size (a barrel trap), and adding organic matter to the trap and a small LED light.

Following a suggestion that

Tekken fish net traps In an alternative approach, fish nets made from Tekken netting have been used (Figure 3.4). These act like a fishing gill net, catching beetles as they try to move through it. In Guam, covering heaps of organic waste with Tekken netting has been successful as it catches fresh adults as they emerge from organic waste, where they have developed, as well as beetles that are returning to the organic matter heaps to lay eggs. Netting can also be used in simple traps baited with pheromone on fences or by looping around the palm trunk to entangle the adult beetles as they move to the palm (Moore et al. 2014).

Figure 5: Tekken.

Trapping has been used successfully for both monitoring and control. The Hoyt trap was used to monitor the decline of beetle numbers over three years, which was associated with a loss of organic matter for larval feeding (Bedford 1975). Pheromone traps baited with E4-MO can be placed at one trap per 10 hectares to monitor populations in order to establish control action thresholds, or they can be placed at high densities, one per two hectares, in order to reduce CRB populations in plantations (Chung 1997). With improvements in trap design, Moore et al. (2014) estimated the capture of 33 per cent of a CRB population, which would have a significant impact on the population especially if combined with other measures. Tekken netting tied around the palm through the leaf axils seems particularly effective in protecting young ornamental palms from attack as it intercepts the beetles as they move towards the feeding site.

2.4 Chemical control

Chemical control measures are most effective on young palms against CRB. Chemical pesticides are used to prevent the adult beetle from damaging the spear and growing point. The insecticide, cypermethrin, is recommended to protect young oil palm replants in CRB-infested areas but only until the palm starts fruiting as the insecticides can damage the beneficial pollinating weevil (Elaeidobius kamerunicus) (Ismael et al. 2009). Moore (2013) also tested use of cypermethrin for control of CRB in coconut palms in Guam and found it effective when applied to young damaged palms. Trunk injection with Thiosultap disodium (Ero 2016) has also been shown to kill beetles in the crown of mature oil palms (Ero pers. comm.). Some insecticide options for CRB have been described by CABI (www.cabi.org/isc/datasheet/37974); however, their use is limited given the intermittent pattern of attack and the growth of the palms making the crowns unreachable. As the target for protection is the base of the frond sheath where the beetle penetrates the petiole, granular formulations are an option to facilitate application. Use of any insecticide should conform to the registration regulations of the country of use and be applied with appropriate care. Guidelines for application of synthetic pesticides are provided in SPC documents (e.g. Crop Protection Manual for Trainees, Honiara, Solomon Islands 2012).

2.5 Biological control

Biological control is the use of natural enemies (predators, pathogens, parasites) to suppress pest populations (Van Driesche and Bellows 1996). In its native range, CRB is attacked by a community of co-evolved natural enemies (reviewed by Bedford 1980), including pathogenic viruses and fungi, predatory carabid and elaterid beetles and parasitic Scolia wasps. The relative impact of each natural enemy species within this native community is poorly known, with additional control strategies often needed to complement biological control in coconut and oil palm plantations. (See IPM section 3.6.)

When CRB-S invaded the Pacific, it was the focus for a substantial biological control programme. The aim was to find one (or more) natural enemies in the native range that could be introduced to the invaded range to suppress CRB-S populations (e.g. Hoyt 1963). This process is known as classical biological control (Van Driesche and Bellows 1996). Among many natural enemies introduced to the Pacific, very few predators or parasites established (Caltagirone 1981). Incidental predation by pigs and chickens on CRB larvae may assist with control of this pest and can be useful for control of larvae in household or community waste piles. Local species of generalist arthropod predators (centipedes, beetles, ants) may feed on CRB larvae; however, there is little evidence that this contributes significantly to CRB control (Hinckley 1967). Only one pathogen provided significant control of CRB-S: the Oryctes rhinoceros nudivirus (OrNV) discovered in Malaysia by Alois M. Huger. (Huger 2005 summarises the history of virus discovery and its use against CRB.) This virus infects CRB larvae and adults, causing death after 6–30 days. Infected adults are weakened prior to death so that they stop feeding, and their mobility and breeding is reduced. Once established in countries invaded by CRB-S, the virus had a significant impact on CRB populations and reduced palm damage (Huger 2005). Another approach to biological control for CRB was to create a biopesticide from a known pathogen. CRB adults and larvae can be infected by strains of the fungus Metarhizium majus (formerly M. anisopliae var. majus). This fungus has been developed into a biopesticide that can be applied to CRB breeding sites in both the native and invaded range (Bedford 2013).

The recent invasion of CRB-G has changed CRB management wherever it is found. CRB-G is not susceptible to the strain of OrNV introduced originally to control CRB-S in the Pacific (Marshall et al. 2017). A new biological control effort is underway in order to identify strains of OrNV from CRB's native range that are effective against CRB-G. Until an effective OrNV strain is discovered, biopesticides containing M. majus are the only option for biological control of CRB-G.

2.6 Integrated pest management (IPM)

Integrated pest management (IPM), is a broad-based approach that integrates practices for economic control of pests. The FAO defines IPM as "the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimise risks to human health and the environment. IPM emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms".

SPC has recommended IPM for management of CRB and includes combination of the factors described above.

For coconut palms planted for subsistence, ornamental purposes, or in commercial plantations, IPM for CRB involves: i) monitoring of palm damage (section 2.5) to detect localised CRB outbreaks and check that control is successful; ii) biological control (section 3.5) with OrNV (in the invaded and native range) and other co-evolved natural enemies (in the native range only); and iii) sanitation (section 3.1) to remove organic waste, dead palms and other potential breeding sites. Sanitation is an essential component of IPM for CRB that complements

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biological control (Huger 2005). Localised CRB outbreaks will occur when breeding sites are left uncontrolled (e.g. after cyclones and tropical storms, when palms are often toppled by high winds and large amounts of green waste is created). Historically, outbreaks of CRB often follow cyclone damage (Jackson and Marshall 2017). A high number of breeding sites are created during plantation renovation, when old palms are felled to make space for replanting. Larvae will develop in the decaying fronds, the trunk and even the root of the felled palm. Some additional options may be incorporated into IPM programmes for coconut, particularly for commercial plantations or ornamental palms. These more costly options include pheromone traps to monitor adult beetle activity and complement it with visual surveys of palm damage. Occasionally, trap catches may be high enough to contribute to population suppression in coconut plantations (Bedford 2013), but this strategy is more relevant to oil palm (discussed below). Commercial products containing the fungus M. majus may be applied to CRB breeding sites that cannot be removed. Insecticide treatments are not recommended for established coconut palms (section 3.4) as there is a potential risk of translocation of insecticides (move within the palm), leaving harmful residues in the coconut. If a recent invasion of CRB is targeted for eradication, insecticides may be necessary for success (Figure 3.6). In this situation, expert advice is needed to determine the most appropriate choice of insecticide, to advise on the length of time residues will persist, and to ensure insecticide- contaminated coconuts are not harvested for human consumption.

For higher value crops, particularly oil palm, the same components are needed as for coconut: monitoring; biological control; and sanitation. More costly IPM components are recommended for oil palm because the crop's financial value makes greater investment in control worthwhile (reviewed by Bedford 2014). Thus, IPM for CRB in oil palm involves: i) monitoring of beetle activity with pheromone traps (section 3.2) and palm damage (section 2.5), particularly for young palms; ii) biological control (section 3.5) with OrNV (invaded and native range) and other natural enemies (native range) plus application of M. majus biopesticides to breeding sites that cannot be removed; and iii) sanitation to remove organic waste (section 3.1), particularly during plantation renewal when large amounts of waste is generated; iv) insecticide treatments (section 3.4) for young palms that are most sensitive to CRB damage. Note that pollinators of oil palm are vulnerable to insecticides, so applications should be scheduled carefully to avoid flowering. When oil palm plantations are renewed, complete clean-up of the organic waste is challenging. In CRB's native range, an additional strategy is to break up and spread the waste as a thin layer, then plant a fast-growing cover crop, often a legume, over the waste matter (Wood 1968).

A decision tree to identify IPM options for coconut and oil palms is presented below (Figure 3.5). This includes decision points to consider potential for eradication of recent CRB invasions as well as management of established CRB populations.

Figure 3.5 IPM decision tree for CRB control in its invasive range. This tree can be used for either CRB-S or CRB-G; however, note that an effective strain of Oryctes virus has not yet been identified for CRB-G.

References

Bedford, Geoffrey O. 1980. Biology, ecology, and control of palm rhinoceros beetles. Annual Review of Entomology 25 (1980): 309–39. Available online at

Gressitt, J. Linsley 1953. The coconut rhinoceros beetle (*Oryctes rhinoceros*) with particular reference to the Palau Islands. Bernice P. Bishop Museum. Bulletin 212. Available online at

Jackson, Trevor, Sean Marshall, Sarah Mansfield and Fereti Atumurirava 2020. Coconut rhinoceros beetle (*Oryctes rhinoceros*): A manual for control and management of the pest in Pacific Island countries and territories. Pacific Community (SPC). Available online at https://tinyurl.com/yxk4u27j

Marshall, Sean D. G., 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, 127-134. Available online at

Pallipparambil, Godshen R. 2015. New Pest Response Guidelines: *Oryctes rhinoceros* (L.) Coleoptera: Scarabaeidae, Coconut rhinoceros beetle. U.S. Department of Agriculture, Animal Plant Health Inspection Service, Plant Protection and Quarantine. Available online at https://tinyurl.com/mpdmvfpt