Paudel et al. *New Zealand Plant Protection 74*(1) (2021) 37–41
https://doi.org/10.30843/nzpp.2021.74.11742

RESEARCH NOTE

Monitoring an invasive coconut rhinoceros beetle population using pheromone traps in Honiara, Solomon Islands

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(Original submission received 31 May 2021; accepted in revised form 26 July 2021)

Summary An invasive population of the coconut rhinoceros beetle (*Oryctes rhinoceros*; CRB) was discovered in Honiara, Guadalcanal, Solomon Islands in 2015. The beetle has caused severe damage to coconut palms in the outbreak area and its continued spread threatens the food security and livelihood of thousands of smallholder farmers in the region. Spread and abundance of the beetle were monitored using bucket traps baited with the aggregation pheromone, ethyl-4 methyloctanoate. Beetles were collected from traps approximately bi-weekly for two periods; one during 2017–18 and the other during 2019–2020. Trap catches showed that CRB was present throughout the whole survey region with significantly higher numbers of female CRB trapped than males. Results indicate a significant 1.5-fold increase in CRB trap catch numbers from 2017–2018 to 2019–2020 despite control efforts. The number of CRB adults trapped also varied between sites and months during both time periods but with no clear patterns. Removal of breeding sites along with strong local quarantine should remain the top priority of the local government to contain CRB expansion within Solomon Islands and beyond.

Keywords *Oryctes rhinoceros*, ethyl-4 methyloctanoate, Honiara, Solomon Islands, pheromone trap

INTRODUCTION

Coconut rhinoceros beetle (CRB: *Oryctes rhinoceros*) is a damaging and, at times, devastating pest of coconut and oil palms in the Asia/Pacific region (Bedford 1980). Adult beetle attack on palms is characterised by damage to the emerging fronds and the appearance of v-shaped notches as if cut with scissors (Fig. 1A). The notches are produced as the beetle cuts through the developing spicule and are revealed as the frond emerges and unfurls. The insect is native to South and Southeast Asia and was inadvertently introduced into the Pacific in 1909 (Bedford 1980). In 2015, a highly damaging population of CRB (CRB-G haplotype) was reported from Honiara, the capital of the Solomon Islands, located on the island of Guadalcanal. This haplotype is tolerant to biological control by commonly used strains of *Oryctes rhinoceros* nudivirus (OrNV) that had kept earlier waves of CRB into the Pacific under control for more than 30 years (Marshall et al. 2017; Paudel et al. 2021). Presence of CRB-G was first confirmed from the specimens (adult beetles and larvae) collected from Panatina, a suburb of Honiara, west of the city centre in January 2015 (Vaqalo et al. 2017). An "emergency response" was called for to respond to the invasion (Jackson 2015). Sanitation and awareness programmes were initiated by Ministry of Agriculture and Livestock (MAL) to attempt control of the pest but have been hampered through lack of funds (Tsatsia et al. 2018).

Pheromone trapping has been used successfully in the past to indicate and monitor the presence of CRB in Malaysia (Chung 1997; Kamarudin et al. 2007) and India (Saminathan et al. 2019), and also provide a relative estimate of abundance (Southwood 1978; Grant 1991). The aim of the current study was to assess the spread and abundance of CRB in the outbreak zone by establishing and monitoring a network of pheromone traps during parts of 2017–18 and 2019–2020.

MATERIALS AND METHODS

Study area and pheromone trap establishment

The study was conducted in Honiara, Solomon Islands. The CRB adult population was monitored during two different time periods: Oct 2017 to June 2018 and Dec 2019 to June 2020. A total of 29 bucket traps baited with the synthetic attractant oryctalure (ethyl 4-methyloctanoate; ChemTica Internacional, Costa Rica) were established during each time period in different geographical locations (Fig. 1B and

1C). This chemical was used as it has been identified as a male-produced aggregation pheromone of CRB and is widely used in monitoring programs against this pest (Hallett et al. 1995; Moslim et al. 2011; Kalidas 2014; Indriyanti et al. 2018). The pheromone bucket traps were constructed from a plastic bucket with a lid (Fig. 1C). Two large holes (diameter 2.8 cm) and 2 small holes (in the centre) were made using a hot wire or a hot rod (Jackson et al. 2020). The pheromone sachet, placed in an upright position inside the bucket, was attached with a wire under the bucket lid. Traps were hung in the tree canopy at approximately 1.5–1.8 m above the ground and the pheromone lures were replaced every two to three months. Traps were monitored bi-weekly and the number of captured CRB adults was recorded and segregated by male and female (Bedford 1980). The raw data were converted to number of CRB adults/trap/month for further analysis. Trap sites were changed between the first and second monitoring periods because there were problems with theft of the buckets at some sites.

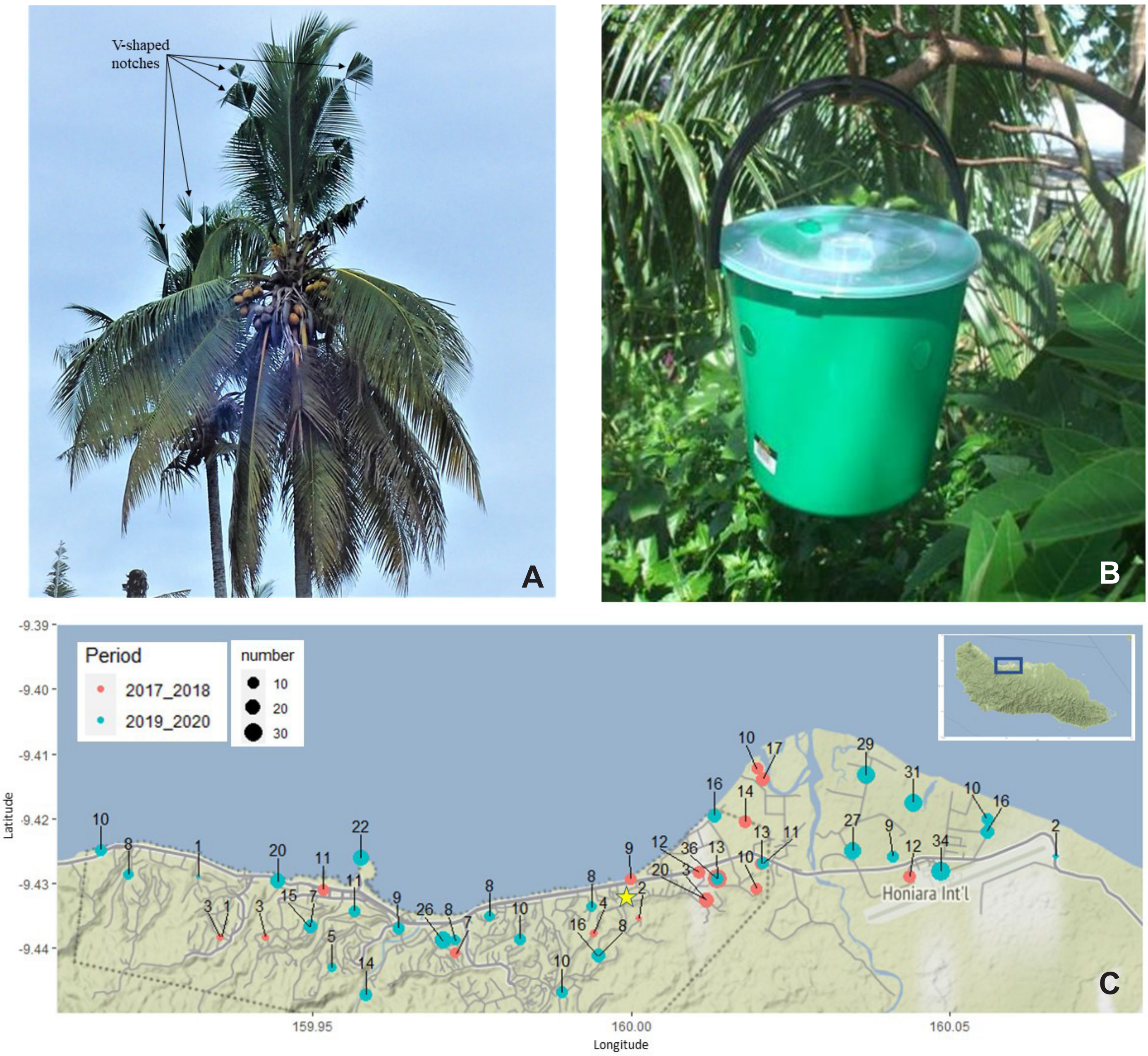

Figure 1 A: Characteristic damage (V-shaped notches) to coconut palm fronds by adult *Oryctes rhinoceros* in Guadalcanal, Solomon Islands; B: Bucket trap containing *Oryctes rhinoceros* aggregation pheromone; C: *Oryctes rhinoceros* monitoring sites in Honiara, Solomon Islands with trap catch numbers from individual traps. Red dots indicate the sites from 2017–2018 and blue dots indicate sites from 2019-2020. The size of each dot is proportional to the number of adults trapped/site. Longitude values are shown on the x-axis and the latitude values on the y-axis. The yellow star (centre-right) indicates the site (Panatina) from where larvae and adults were first collected in Jan 2015 and confirmed as *O. rhinoceros*. The inset at the top right is the island of Guadalcanal and the rectangle shape within the map represents the study site within Honiara.

Data analysis
Insect trap data were analysed via generalised linear model (GLM) with Poisson distribution using Minitab software (version 18) (Demétrio et al. 2014; Minitab 2018). Site coordinates were mapped using 'R Studio' software with data packages: "ggplot" and "ggmap" (RStudio 2020).

RESULTS AND DISCUSSION
Average monthly trap catches of CRB adults during 2019–2020 was significantly greater than 2017-2018 ($p < 0.001$, Fig. 2A). On average, number of CRB adults trapped increased by 1.5-fold between two time periods (from 4.85 ± 0.37 beetles/trap/month during 2017–2018 to 7.23 ± 0.40 beetles/trap/month during 2019–2020). Beetles were trapped throughout the whole outbreak zone with considerable variation between traps (Fig. 1C). Trap catches ranged from 1 adult/trap/month to 36 adults/trap/month. There were a few sites in and around Honiara International airport (marked as Honiara Int'l on Fig. 1C) where the trap catches were particularly high ranging from 9 to 31 adults/trap/month. While data from pheromone-baited traps are not always a reliable predictor of the pest's abundance (Adams et al. 2017; Žunič-Kosi et al. 2019), this study suggests an increase in the invasive CRB population between the two trapping periods. This could be due to dead palms from during the first period becoming available as breeding sites for the expanding population. Increases in CRB infestations within Honiara after the invasion have been reported (Vaqalo et al. 2017; Tsatsia et al. 2018). For example, 70% of palms in Honiara were damaged from CRB during 2017 based on a rapid damage assessment survey (Vaqalo et al. 2017). These results also indicate that the sanitation and other emergency response programmes conducted by BSI and Solomon Islands government have not been sufficient to prevent the CRB population in Honiara expanding from the initial foci of infection.

Numbers of trapped female beetles were 1.7-fold higher than the males (7.63 ± 0.44 females/trap/month versus 4.50 ± 0.30 males/trap/month) (Fig. 2A). This result suggests a higher rate of attraction of female beetles towards the aggregation pheromone and is consistent with other studies using this pheromone (Indriyanti et al. 2018; Maruthadurai & Ramesh 2020). There were no recognisable trends in terms of monthly catch number between two time periods. The number of trapped CRB adults varied between months of the year and ranged from 2 to 10 beetles per trap per month (Fig. 2B). Catch during 2017–2018 was highly variable with peaks in November, February, and April. During 2019–2020, CRB adult numbers were highest in May, whereas the fewest were caught in June. CRB is a very recent invasive pest, so it is likely that the population has not yet reached carrying capacity or equilibrium in this region.

As the beetle population continues to expand, serious impacts on both coconut yields, and livelihoods of smallholder farmers are expected. Therefore, there is a need for a greater involvement of local communities, non-government organisations and private entities (e.g. coconut and oil palm industries) with sanitation efforts and public awareness campaigns. Damage assessments, and monitoring of CRB numbers with pheromone traps (Jackson et al. 2020), should be conducted pre- and post-sanitation so that the impact of control efforts is known (Tobin et al. 2013). The fungus *Metarhizium majus* is known to control a range of beetles so its application to potential breeding sites should be considered (Latch & Falloon 1976; Ramle et al. 2006; Mohan et al. 2010), particularly in logging areas where thorough sanitation is not feasible. Local extension officers should be supported with training and resources to conduct this work, so that they are not dependent on staff from MAL travelling out from Guadalcanal. A stronger awareness campaign and standardised legal framework is urgently required to effectively enact internal biosecurity measures, not only among provinces but also between islands within each province (McNeill et al. 2015). For example, restricting port operations at night may reduce movement of adult beetles, which are attracted to lights. Similarly, strict regulations for logging and mining activities in provinces like Choiseul and Isabel may potentially help curb the spread.

CONCLUSIONS
Pheromone trapping confirmed that CRB has spread throughout the whole zone surrounding Honiara between the first report of incursion in 2015 and the systematic sampling carried out in this study. In partnership with local and regional stakeholders, government should focus on removing breeding sites, enforce strong local quarantines and develop a robust public awareness campaign to manage the CRB population.

ACKNOWLEDGEMENTS
This work was funded by MFAT project PF 9-548. In-country support from the Ministry of Agriculture and Livestock (MAL) team was greatly appreciated.

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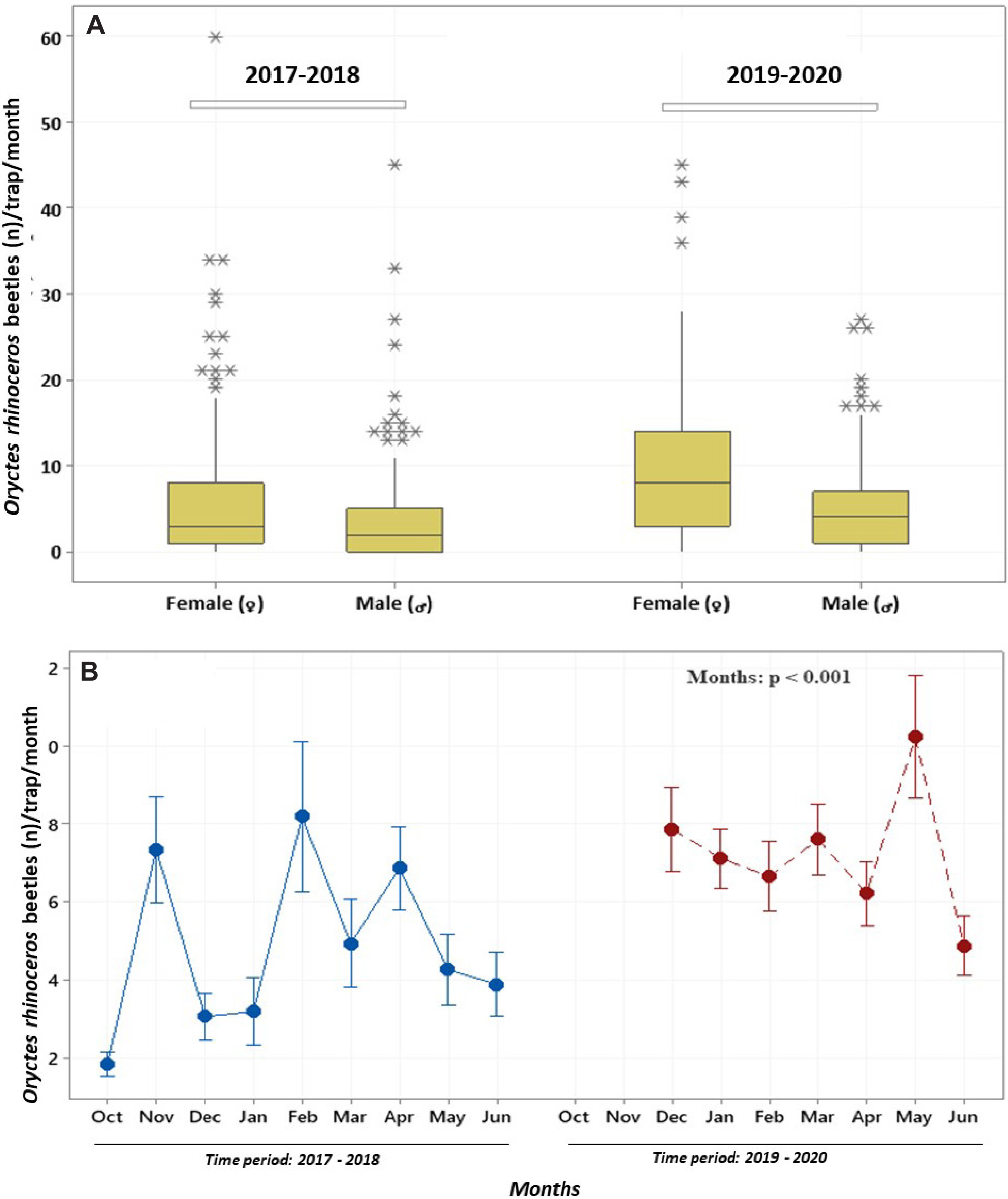

Figure 2 A: Numbers of *Oryctes rhinoceros* adults (male and female) captured in pheromone traps during 2017–2018 and 2019–2020. The box indicates the median (central line) and upper and lower quartiles for the trap catches and "whiskers" above and below the box correspond to the minimum and maximum number of *Oryctes rhinoceros* adults trapped outside the inter-quartile range. The asterisk sign (*) represents outliers; B: Monthly catch numbers for *Oryctes rhinoceros* adults in pheromone traps around Honiara during 2017–2018 and 2019–2020.

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