# Using expert knowledge and field surveys to guide management of an invasive alien palm in a Pacific Island lowland rainforest

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**Abstract** Invasive alien ornamental plants are a global problem, especially on oceanic islands, and can have severe impacts on native biodiversity. *Pinanga coronata,* is an ornamental palm tree that can form mono-dominant stands in its native habitat and is widely cultivated throughout the tropics. Here we investigate the introduction, spread, impact and management of this invasive palm in the Fiji Islands, using extensive discussions with local experts and field surveys. *Pinanga coronata* was introduced in the 1970s to the Colo-i-Suva area, eastern Viti Levu island, Fiji´s principal island, and has since become invasive in mahogany plantations and lowland rainforest. It has also been introduced and is becoming invasive on the western side of that island. However, the distribution of *P. coronata* remains geographically limited to the immediate vicinity of introduction sites but it is rapidly spreading. In each location, the species has formed mono-dominant stands in the understorey and appears to be displacing native plant species, as suggested by a negative correlation of its abundance with that of native tree ferns. This highlights the need for rapid control of *P. coronata* in Fiji. Local experts state management should involve manual removal of seedlings and saplings, killing of adult palms by injection of herbicide, and education and legislation to prevent the further spread of the species. Based on these recommendations and field data, management actions to control *P. coronata* are proposed and steps to develop these into a management plan are discussed. Given *P. coronata* threatens native biodiversity in Fiji and has the potential to invade other rainforest ecosystems in the tropics, proposed management approaches are urgent and relevant for other tropical countries.

**Keywords:** biodiversity loss, biological invasion, island biology, mahogany plantation, management plan, mono-dominant protected area, ornamental

## INTRODUCTION

The tropical Pacific islands are highly vulnerable to the impacts of invasive alien plant species because of the region's geographic isolation and evolutionary traits that leave species vulnerable to competition (Gurevitch & Padilla, 2004; Denslow, et al., 2009; Caujapé-Castells, et al., 2010; Woinarski, 2010; Minden, et al., 2010b). The region has the greatest rate of increase in the number of invasive alien plant introductions with respect to area in the world (Van Kleunen, et al., 2015). Furthermore, invasive species are a major cause of extinction on Pacific Islands (Tye, 2009). With increasing economic development in nations of the Pacific, the diversity and impact of invasive plants in the region is likely to increase (Kueffer, et al., 2010).

*Pinanga coronata*, or ivory cane palm, is an ornamental palm tree that is cultivated and traded throughout the tropics (Palmpedia, 2017). The palm is native to lowland rainforests in Java and Sumatra (Kimura & Simbolon, 2002) and has been identified as a potentially invasive alien plant species on Pacific and other oceanic islands (Meyer, et al., 2008). Introduced to Fiji in the 1970s for its ornamental properties, the palm has become invasive in lowland rainforest and mahogany plantations (Keppel & Watling, 2011) but the current extent of its distribution is unknown. The Fiji Islands have a unique and highly diverse biota that is severely threatened by habitat loss, exploitation, pollution and invasive species (Myers, et al., 2000; Keppel, et al., 2014).

Pacific small island developing states (SIDS) have limited information, funding and trained professionals for invasive species management and conservation in general (Tye, 2009; Keppel, et al., 2012). However, local communities and experts often have extensive knowledge about their environment (Lefale, 2010; Keppel, 2014; Keppel, et al., 2015). In Fiji, expert knowledge plays a crucial role in conservation and protected area management (Keppel, 2014) and has provided important information about the conservation status of rare trees (Keppel, et al., 2015).

Using results from a quantitative field survey and qualitative expert knowledge, we demonstrate that *P. coronata* is threatening biodiversity and displacing native tree ferns in lowland rainforests and mahogany plantations. We then combine these two lines of evidence as the basis for a management framework to address the *P. coronata* invasion and its impact on native biodiversity in Fiji. Acknowledging the current challenges in the Pacific for invasive species management (Tye, 2009), the framework incorporates methods that are economically viable, develops capacity building and promotes awareness for all stakeholders related to the *P. coronata* invasion.

## METHODS

### Site description

The Fiji Islands include over 300 islands and islets in the western South Pacific (Mueller-Dombois & Fosberg, 1998). Fiji has a tropical climate with a wetter season from November to April and a drier season from May to October. Due to the south-east trade winds orographic rainfall produces higher precipitation in the south-east of topographically more complex islands (Mataki, et al.,

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2006). The capital of Fiji, Suva, is in the south-east of the archipelago's largest island, Viti Levu, and has an average annual rainfall of about 3,000 mm and an average surface temperature of 25.4°C (Mataki, et al., 2006).

The Colo-i-Suva area is approximately 12 km north of Suva (Fig. 1) and has four protected areas. The Colo-i-Suva Forest Park has no legal status but comprises the Colo-i-Suva Forest Reserve (FR; 370 ha) and the Maranisaqa-Wainiveiota FR (77 ha). Adjacent are the Savura FR (448 ha) and the Vago FR (24.7 ha). The area is mountainous and the vegetation communities are fragmented, lowland rainforest and mahogany plantations amongst agricultural and urban landscapes. The Savura and Vago FRs are mostly comprised of lowland native rainforest with minimal disturbance. These FRs constitute a major catchment for the Savura Creek, which secures the water supply for the capital city (Keppel, et al., 2005). Colo-i-Suva Forest Park is a mahogany plantation that has not been commercially logged since its establishment in the 1960s (Tuiwawa & Keppel, 2012). The Forest Park has conservation values because the mahogany plantations support a rich native understorey (Tuiwawa & Keppel, 2012), and is also frequented for recreational activities including local and international tourism (Malani, 2002).

### Study species

*Pinanga coronata,* is native to western Indonesia, on Java and Sumatra where it is abundant in the rainforest understorey and occurs from sea-level to about 1800 m (Kimura & Simbolon, 2002). The species can be found on steep hillsides, lowland flats and exposed ridges, and juvenile palms are found at higher densities on lower slopes and moist areas (Kimura & Simbolon, 2002). Tolerating low light conditions, *P. coronata* forms mono-dominant clusters in the rainforest understorey, where it can reproduce sexually and asexually from vegetative shoots (Kimura & Simbolon, 2002; Kimura & Simbolon, 2003; Witono & Kondo, 2007). *Pinanga coronata* has rapid growth rates, reaches fecundity at <1 m in height, and can then continuously reproduce (Kimura & Simbolon, 2002).

*Pinanga coronata* has shown signs of becoming invasive in Hawaii and Tahiti (Daehler & Baker, 2006; Meyer, et al., 2008), but is not believed to currently be threatening biodiversity (US Forest Service, 2015). In Fiji, *Pinanga coronata* was introduced to the Colo-i-Suva area on Viti Levu during the 1970s for its ornamental properties (Keppel & Watling, 2011) and was first recognised as a potentially invasive species in 1992 (Watling & Chape, 1992). Since its introduction the palm has become dominant in the understorey of mahogany plantations (Watling, 2005) and invasive in native lowland rainforest, forming mono-dominant stands (mature palms and saplings) of several metres in diameter (Keppel & Watling, 2011).

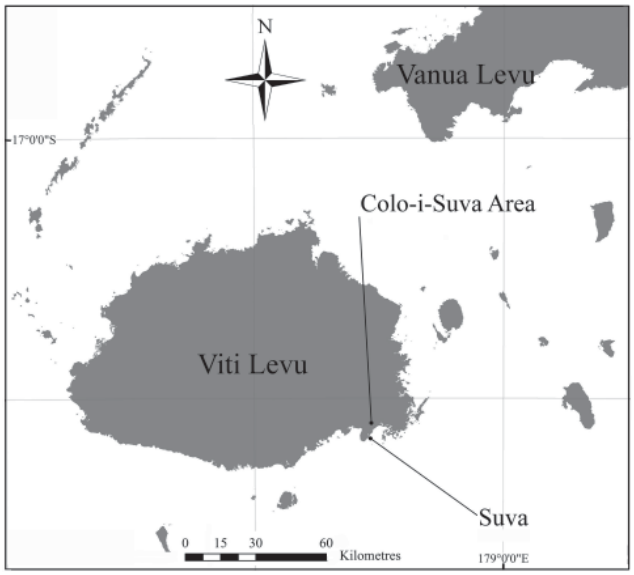


**Fig. 1** Study locations on Fiji's largest island, Viti Levu.

### Interviews

Experts were consulted by the lead author through informal discussions during fieldwork, and in semi-structured interviews in the office from July to September 2016, regarding the invasion history of *P. coronata*. Discussions were open ended but the key themes were the introduction history, distribution and dispersal, impact on native flora and recommended management of *P. coronata*.

### Field survey

A systematic field survey was conducted in the Colo-i-Suva Forest Park and Savura FR. The aim was to identify areas of management priority and to determine if *P. coronata* is spreading. Using the Fishnet Tool in ArcMap 10.2.2, a 300 x 300 m grid with 11 columns and 15 rows was overlaid on the boundaries of Colo-i-Suva Forest Park and Savura FR. The centre point of each grid cell was imported into a Garmin Etrex 30® as waypoints. A 5 x 5 m plot was placed at each waypoint within the boundaries of the two forest reserves.

The abundance of *P. coronata* was recorded in ninety-two 5 x 5 m plots in Colo-i-Suva Forest Park (54 plots) and Savura FR (38 plots). The abundance of the palm was determined as the number of mature (stem > 1 m in height), juvenile (>0.5–<1.0 m) and seedling (< 0.5 m) palms, calculated by counting their numbers in each plot. The abundance of tree ferns was estimated by counting the number of mature (caudex > 1 m), juvenile (0.1–1 m) and tree fern saplings (< 0.1 m) (Ash, 1986; Ash, 1987). Additionally, opportunistic sightings of isolated *P. coronata* palms were recorded on a GPS Etrex 30®. Palms were only considered isolated if they were not near other *P. coronata* palms and were not a part of a mono-dominant stand.

## RESULTS

### Introduction history

Although there are no official records about the exact location and year *P. coronata* was introduced to Fiji, it was likely first introduced to a quarantine station north of Fiji's capital Suva (Fig. 2), for the propagation and trade of exotic palm trees. Palms were likely sold from this location to horticulturalists around Fiji. *P. coronata* is believed to have spread from the site through the surrounding, now cleared, mahogany plantation. Although the quarantine site has been abandoned and is now surrounded by an agricultural landscape, *P. coronata* is still present around the remains of the buildings.

The first official record of *P. coronata* in Fiji is a specimen in the South Pacific Regional Herbarium (number DA 18579) collected from the former Emperor Gold Mine guesthouse at Colo-i-Suva (about 2 km north of the former quarantine station) by Saula Vodonivalu on 16 February 1975. The habitat was described as a roadside and the specimen was flowering, with the tallest palm being approximately seven feet. This specimen originated from plantings around the mine's guesthouse, which were planted for ornamental purposes. This guesthouse was on the site of what is now an agricultural property that grows fresh produce for Joe's Farm supermarkets (Fig. 2). At

some stage *P. coronata* was also introduced to a residential property within the interior of Colo-i-Suva Forest Park, which had a diverse collection of exotic ornamental plant species. This garden is still private property but the lease will return to the Ministry of Fisheries and Forests.

### Distribution and dispersal

We believe that the distribution of *P. coronata* is currently restricted to the Colo-i-Suva area but is spreading rapidly. Our observations record that the species has now spread through the Savura and Vago FRs, occupying a total area of about 1,500 ha, and is most dense in the mahogany plantations near Joe's Farm and in the north of Colo-i-Suva Forest Park (Fig. 2).

*P. coronata* is cultivated ornamentally in several gardens in Suva, including the University of the South Pacific, Laucala Campus. It has escaped from cultivation in and around the Garden of the Sleeping Giant near Nadi Airport, on the western side of Viti Levu (Fig.1) and is distributed as an ornamental by landscapers and horticulturists in Suva and across Fiji, especially to hotels and tourism resorts. No estimates of the numbers of palms dispensed is available.

Within Colo-i-Suva Forest Park, we observed *P. coronata* to be most dense along streams and watercourses. We believe that one means of dispersal for the species is by seeds falling into waterways leading to establishment downstream. Once established near streams, *P. coronata* probably expands its distribution by moving up slopes bordering water courses.

Birds are believed to disperse *P. coronata* seeds. DW found a *P. coronata* seedling sprouted in his garden approximately nine kilometres from the introduction locations and main infestations. In the Colo-i-Suva area (Colo-i-Suva Forest Park and Savura FR) dense patches of *P. coronata* seedlings are commonly found below the canopy of tall native (especially *Gymnostoma vitiense*; Casuarinaceae) and exotic trees (*Maesopsis eminii*; Rhamnaceae) used as perching locations by native members of the Columbidae family, suggesting that fruits are eaten by birds that forage in the lower canopy and understorey . The island thrush, (*Turdus poliocephalus*) and the red-vented bulbul (*Pycnonotus cafer*) are likely dispersers in mature and open/edge forests, respectively.

### Impact on native flora

We found mono-dominant stands of *P. coronata* in the understorey around all introduction sites in the Colo-i-Suva area. In the north of Colo-i-Suva Forest Park, *P. coronata* comprises up to 70% of the understorey and is outcompeting native understorey plants, especially tree ferns, and reducing their sapling regeneration (Mathieu 2015). Similarly, the palm is also abundant and outcompeting native species in the understorey of lowland rainforests. Therefore, *P. coronata* is considered to have the potential to become dominant and outcompete native plant species in Fiji's native lowland rainforests.

*Pinanga coronata* was present in 54 % of the plots surveyed in Colo-i-Suva Forest Park and 17 % of plots in Savura FR. It was mono-dominant in the understorey of 19 plots (21 % of all plots), 18 of which were in the north of Colo-i-Suva Forest Park (dominated by mahogany plantations) and the other was in the north of Savura FR (consisting of native lowland rainforest). Visual inspection of the distribution map (Fig. 2), shows the highest density near putative source locations and several isolated populations in both forest reserves.

Palm cover in the understorey displayed a strong negative correlation with all three tree fern classes, tree fern saplings ($\rho \geq -0.26$, $p < 1.2 \times 10^{-2}$), juvenile tree ferns ($\rho \geq -0.38$, $p < 3.7 \times 10^{-4}$) and mature tree ferns ($\rho \geq -0.33$, $p < 1.7 \times 10^{-3}$). With increasing palm cover in the understorey, the abundance of tree ferns decreased, especially when palm cover exceeded 50 % (Fig. 3). Therefore, results from the plots surveyed reinforce our field observation-based belief that *P. coronata* is displacing native species.

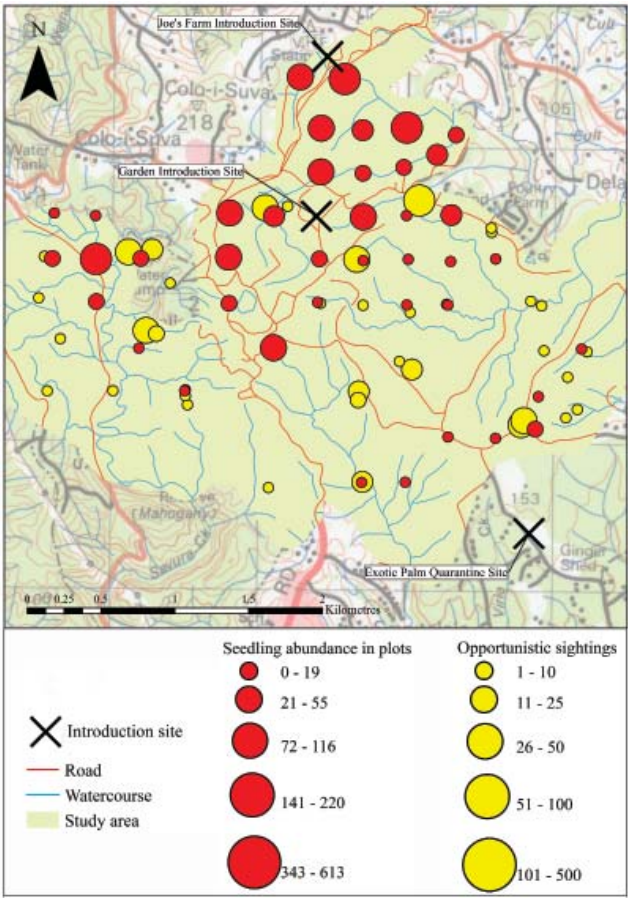


**Fig. 2** The distribution of palm seedlings in plots and isolated populations in Colo-i-Suva Forest Park and Savura Forest Reserve.

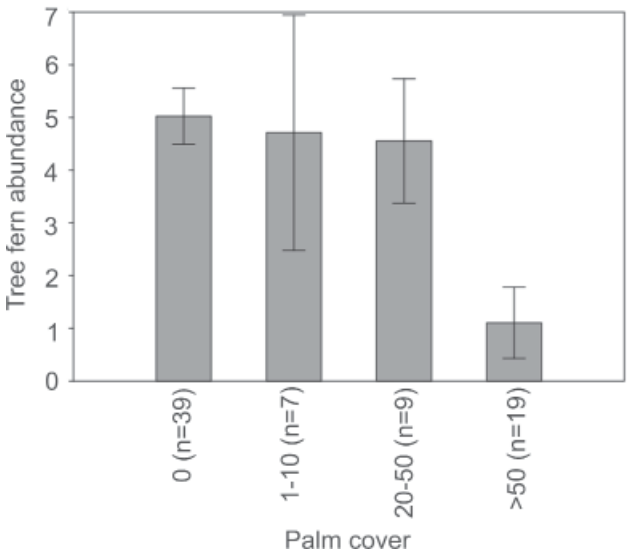


**Fig. 3** The comparison of tree fern saplings and palm cover in the understorey. Tree fern abundance on the y-axis and palm cover on the x-axis. n = number of plots in the class.

### Recommendation to manage *Pinanga coronata*

We believe that *P. coronata* must be listed as a pest species and be controlled as a matter of urgency. Control could be via manual removal of *P. coronata*, starting with seedlings and juvenile palms in isolated populations. Chemicals may be required to kill adult palms, because they are difficult to remove and the species can reproduce vegetatively from the base. The exotic tree *Maesopsis eminii*, which is spread throughout the Colo-i-Suva Forest Park, may need to be controlled concurrently, as this tree attracts frugivorous birds and *P. coronata* seedlings are often abundant at its base.

There also needs to be action to stop further propagation and reintroductions by horticulturalists. Furthermore, education for communities, tourism operators and the Biosecurity Authority of Fiji about the palm and its threats to native biodiversity is essential to solicit maximum support from the public and the government.

## DISCUSSION

In our study, qualitative and subjective data are supported and reinforced by quantitative and objective field data. Combined, these results make a strong case that *P. coronata* is continuing to spread through mahogany plantations and native lowland rainforest in the Colo-i-Suva area. Both observations and a negative correlation between the abundance of palms and native tree ferns suggest that the introduced palm is displacing native tree ferns. Hence, both expert opinion and field data demonstrate the detrimental impact and potential threat of *P. coronata*, highlighting the need for swift and effective management actions.

However, before any management can be effectively implemented, knowledge of the exact distribution of *P. coronata* (Panetta & Lawes, 2005) and consensus among key stakeholders about the need for urgent management is needed. Knowing the palm's distribution in the Colo-i-Suva area will not only define the target area for management but also determine the stakeholders that need to be involved. Support from the most influential stakeholders will be essential for establishing and implementing a successful conservation and management plan (Keppel, et al., 2012; Moon, et al., 2015; Lenz, 2016). All major stakeholders, especially the Fiji Forestry Department and Biosecurity Authority of Fiji, need to agree that *P. coronata* is a major threat to native biodiversity and an urgent management priority. Assuming that these pre-requisites will be attained, we propose a management framework (Table 2) using a decision and risk analysis based on our knowledge and available quantitative data (Maguire, 2004; Stohlgren & Schnase, 2006; Lenz, 2016). We hope that proposing this framework will hasten the development and implementation of an effective management plan.

### Management framework

Considering the high threat of *P. coronata* to native biodiversity and that its distribution is still relatively restricted, the overarching aim of a management plan should be to eradicate the species (Keppel & Watling, 2011). Eradication is defined as the total removal of all individuals, including seeds, and ensuring that reintroduction will not occur (Myers & Bazely, 2003; Meyer, 2014). However, there have been very few successful invasive plant eradications in the Pacific Islands and these were restricted to species confined to small geographic areas (Meyer, 2014). Additionally, eradication is not achievable without containment (Panetta & Lawes, 2005). Therefore, a feasibility study combining the known biological information of *P. coronata* with the total extent of the invasion (invasion syndrome) will need to be conducted to determine if eradication is achievable with the resources available (Panetta, 2015). Due to this uncertainty about the feasibility of eradication, we focus our discussion about management on control measures to reduce the abundance and spread of *P. coronata*.

Prior to control, stakeholders including the Ministry of Fisheries and Forests, NatureFiji-MareqetiViti (NFMV) and the University of the South Pacific (USP) should develop a management plan. The framework presented here could serve as a starting point. Coordinated efforts by multiple parties will be more efficient (Stohlgren & Schnase, 2006) and have a greater chance of success when decision makers for protected areas support the strategy (Foxcroft, et al., 2008). The involvement of NFMV is important because they have a strong record of effectively engaging with communities and decision-makers to achieve positive conservation outcomes (Morrison, et al., 2012). It is recommended that NFMV be the primary coordinators because invasive species management facilitated by a non-governmental organisation (NGO) that promotes education and stakeholder communication has greater chances of success (Epanchin-Niell, et al., 2010).

The second stage of management should aim to investigate the best method to control *P. coronata* through a feasibility trial. Currently there is a paucity of information on best practice for palm control (Meyer, et al., 2008) and most methods are species-specific (Langeland, et al., 2011). A pre-control feasibility study is necessary to determine which method will be the most effective (Meyer, 2014), as we have outlined in Table 1. Physical removal of palm seedlings is one of the methods to be trialled, as this has been shown to be successful at reducing seedling and juvenile abundance (Langeland, et al., 2011).

**Table 1** Recommended control measures for *P. coronata* that should be trialled in a feasibility study based on literature on invasive palm management (Dovey, et al., 2004, Langeland & Stocker, 1997, Langeland, et al., 2011) and opinions from the authors. Suggestions from literature = LT and opinion from experts = AU. *Biocontrol is mentioned because it could be a successful control method if an appropriate control agent is found. However, biocontrol is not recommended at this stage and should only be considered if all other methods are ineffective and not feasible.

| Management aim | Age target | Method |
|---|---|---|
| Control | Seedlings and juveniles | Hand pulling and removed from the area [AU] |
| Control | Seedlings and juveniles | Hand pulling and tied to a tree [AU] |
| Control | Mature individuals and clumps | Crown removal and apply herbicide to the stem [LT and AU] |
| | Mature individuals and clumps | Inject herbicide into the apical bud [LT] |
| Reduce seed load | All fruiting palms | Removal of flowers [LT] |
| Control | | Biocontrol*[LT] |

**Table 2** Summary of the recommended management framework proposed to control *P. coronata* in the Colo-i-Suva area, on Viti Levu, Fiji. NFMV=NatureFiji-MareqetiViti.

| **Aim:** Control *P. coronata* in the Colo-i-Suva area, on Viti Levu, Fiji | |
|---|---|
| **Objectives** | **Actions** |
| STAGE 1: Producing a management plan through stakeholder communication | |
| Create a management plan through stakeholder engagement<br>NFMV to formalise the management plan and education programmes | Facilitate a formal discussion between stakeholders to develop a management plan.<br>Develop an education programme for stakeholders and the community.<br>Formalise a regular method for communication between stakeholders. |
| STAGE 2: Pre-control feasibility study | |
| Conduct a pre-control feasibility study | Trial different control methods (Table 1). |
| STAGE 3: Control *P. coronata* in the Colo-i-Suva area | |
| Control *P. coronata* in the Colo-i-Suva area | Target isolated and juvenile *P. coronata* populations.<br>Remove the low-density populations in the centre and south-east of Colo-i-Suva Forest Park.<br>Progressively control palms towards the dense populations in the north of the Colo-i-Suva area<br>Simultaneously reduce the seed load and foliage area in the dense populations in the north of the reserves. |
| STAGE 4: Post-control monitoring and reducing the threat of reinvasion | |
| Post-control monitoring**<br>Reduce the threat of reestablishment** | Periodically monitor areas where *P. coronata* has been controlled and investigate responses in native vegetation.<br><br>Plant native tree ferns in areas that are vulnerable to reinvasion and monitor propagation success. |
| STAGE 5: Prohibiting the trade of *P. coronata* in local horticulture | |
| Ensure that *P. coronata* is not reintroduced into the natural environment | Ban the trade of *P. coronata* in the horticulture and tourism industries. This will require the species to be listed as a pest with involvement from the Biosecurity Authority of Fiji.<br>Find a native non-invasive palm that can replace the trade of *P. coronata*. |

**Stages three and four should be conducted simultaneously. After control efforts have removed isolated palms monitoring should take place before the dense *P. coronata* populations are managed.

There are two approaches commonly used with herbicide applications for managing clonal palms that should be trialled. The first method is cutting the palm below the crown and treating the cut stem with herbicide and the second method is injecting herbicide directly into the palm's apical bud (Langeland & Stocker, 1997). In Indonesia, densities of the invasive palm *Arenga obtusifolia* decreased and native rainforest vegetation successfully regenerated, when the palm was injected with herbicide (Konstant, 2014; Nardelli, 2016). A combined approach of applying chemical herbicides and physical removal could be implemented but has had varied success for palm species, like *P. coronata*, that can vegetatively reproduce (Langeland & Stocker, 1997; Langeland, et al., 2011).

After determining the most effective method, the third stage of management should attempt to control the spread and reduce the distribution of *P. coronata*. We consider that juvenile plants in isolated populations should be controlled first. Prioritising low-density populations will be the most efficient at containing the invasion and reducing the threat to endemic, rare and threatened plant species without significantly increasing the cost (Higgins, et al., 2000). Targeting mature and juvenile individuals in isolated populations is a recommended strategy for other invasive plants in the Pacific Islands and likely to be more successful than removing large stands (Meyer, et al., 2011).

Although not recommended as an initial control method for *P. coronata*, biocontrol may be required if physical efforts fail to control the spread. Dovey, et al., (2004) recommends the use of biocontrol in the Pacific Islands because it is resource efficient and can strengthen stakeholder partnerships. Biocontrol is typically applied when the distribution of an invasive plant is too large to be controlled by physical methods but is expensive and requires time-consuming host-specificity tests to ensure native plants from the same family will not be negatively affected (Meyer, 2014). However, reduced foliage cover of an invasive tree due to biocontrol has resulted in the regeneration of understorey species in other Pacific Island rainforests (Meyer, et al., 2012).

Monitoring (stage 4) should take place as control efforts (stage 3) of the different *P. coronata* populations progress. It is critical that management efforts are long-term and control sites are periodically monitored to ensure that the palm does not regenerate from its seed bank, the longevity of which is currently not known, and to understand changes in the vegetation community in response to efforts (Blossey, 1999; Foxcroft, et al., 2008). When invasive alien plants are removed from Pacific rainforests follow-up control efforts are often required (Minden, et al., 2010a, b).

Management should aim to stop *P. coronata* reinvading controlled areas. In healthy native forest ecosystems,

the succession by native flora will naturally occur, but management may be required to reduce the likelihood of invasive plants re-establishing (Awanyo, et al., 2011). Planting native species is an expensive but effective method of reducing the risk of reinvasion (Langeland, et al., 2011). In the Colo-i-Suva region, planting tree ferns could be a novel and appropriate approach to reduce the likelihood of *P. coronata* re-establishing, because tree ferns are native and abundant in the area, especially on disturbed sites (Tuiwawa, 1999; Keppel, et al., 2005).

The final stage is to ensure that *P. coronata* is not introduced into the environment again. This would require the species to be listed as a pest plant under legislation outlined in the Biosecurity Promulgation 2008 act (Biosecurity Authority of Fiji, 2008), ideally at the beginning of the management process to provide legal support for any efforts (Lenz, 2016). Adequate enforcement of the legislation may require training and improved technical expertise within Biosecurity Authority of Fiji. Current palm stocks in local nurseries and ornamental plantings should be identified and controlled to ensure that *P. coronata* is not reintroduced (Meyer, et al., 2008; Lenz, 2016). The latter will be difficult on privately owned properties. Involving the horticultural industry is fundamental for success because they are integral in preventing continuous reintroduction through ongoing plantings (Meyer, et al., 2008).

## CONCLUSION

Our opinions and field data agree on the considerable threat that *Pinanga coronata* is posing to native biodiversity. They also show that the palm is expanding its distribution and spreading into native rainforest ecosystems. There is little doubt that it will continue to do so, unless it is effectively and swiftly managed. Such management would require a thorough and effective management plan suitable to the SIDS in the Pacific and developed through participation by all key stakeholders. Given the evidence that the palm is threatening biodiversity, we propose a framework that could serve as a roadmap for developing and implementing a management plan.

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