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## Invasive alien palm *Pinanga coronata* threatens native tree ferns in an oceanic island rainforest

Michael J. B. Dyer<sup>A,B,I</sup>, Gunnar Keppel<sup>A,C,D</sup>, Marika Tuiwawa<sup>E</sup>, Sainivalati Vido<sup>F</sup> and Hans Juergen Boehmer<sup>G,H</sup>

<sup>A</sup>Natural and Built Environments Research Centre, School of Natural and Built Environments and Future Industries Institute, University of South Australia, Mawson Lakes Campus, GPO Box 2471, Adelaide, SA 5001, Australia.

<sup>B</sup>United Nations Development Program, MCO for Cook Islands, Niue, Tokelau and Samoa, Apia, Samoa.

<sup>C</sup>Future Industries Institute, University of South Australia, Mawson Lakes Campus, GPO Box 2471, Adelaide, SA 5001, Australia.

<sup>D</sup>Biodiversity, Macroecology and Biogeography, Faculty of Forest Sciences, University of Goettingen, Büsgenweg 1, 37077 Göttingen, Germany.

<sup>E</sup>South Pacific Regional Herbarium, Faculty of Science, Technology and Environment, University of the South Pacific, Suva, Fiji.

<sup>F</sup>Forestry Department, Ministry of Fisheries and Forests, Suva, Fiji.

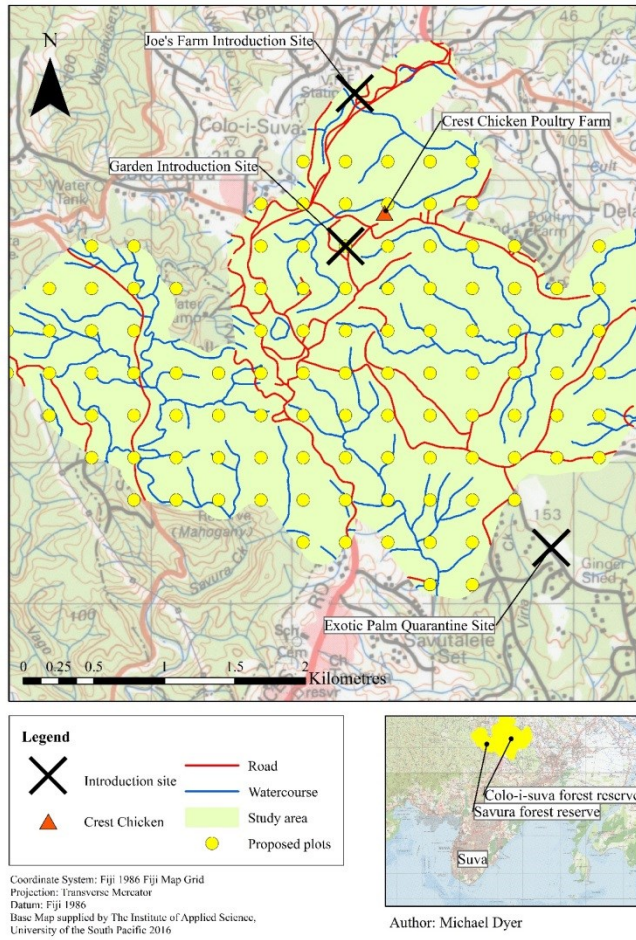
<sup>G</sup>School of Geography, Earth Science and Environment, Faculty of Science, Technology and Environment, University of the South Pacific, Suva, Fiji.

<sup>H</sup>Institute for Applied Ecological Studies (IFANOS), Baerenschanzstrasse 73, Nuremberg, Germany.

<sup>I</sup>Corresponding author. Email: [dyermj13@gmail.com](mailto:dyerMJ13@gmail.com)

## Supplementary Materials

### Sampling design



**Figure S1.** The systematic grid sampling design applied in Colo-i-Suva Forest Park and Savura Forest Reserve on Viti Levu, Fiji, to assess the abundance of *Pinanga coronata* and native tree ferns. Crosses indicate the locations of known introduction sites of *P. coronata*.

## S2 - Description of the response and explanatory variables

**Table 1. The response variables measured in each 25 m<sup>2</sup> plot and a brief description of the method used to obtain their values.**

Response variable	Method description
Number of palm clumps	The number of palm clumps.
Number of stems	The number of stems in each clump. If a palm was mature but had not formed a clump, it was considered to have only one stem.
Mean number of stems	The sum of stems per plot was divided by the number of clumps.
Number of palm seedlings	The number of seedlings (< 0.5 metres in height).
Palm cover (%)	The crown area of each palm was estimated using a measuring tape. The total crown area of palms in a plot was divided by the area of the plot to obtain an estimate of palm cover.
Mean palm height (metres)	The height of each palm was measured and the sum of each palm's height was divided by the number of palm stems.
Max palm height (metres)	The height of the tallest palm in the plot.
Juvenile tree fern	Abundance of tree ferns between 0.1 - 1 metre in height.
Mature tree fern	Abundance of tree ferns > 1 metre in height.
Tree fern saplings	Abundance of tree ferns < 0.1 metre in height.
Tree fern cover (%)	Calculated by measuring the frond area of each tree fern. The total frond area in a plot was divided by plot's area to obtain an estimate of tree fern cover.
Tree fern volume	Volume was estimated by multiplying the basal area of the caudex by its height
Maximum tree fern height (metres)	Tallest tree fern in the plot.
Minimum tree fern height (metres)	Shortest tree fern in the plot (excluding saplings).
Mean tree fern height (metres)	The mean height of tree ferns in the plot (excluding saplings).

**Table 2. The explanatory variables measured in each 25 m<sup>2</sup> plot and the method description to obtain their values.**

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Explanatory variable	Method description
Habitat type	Classified if the plot was in a mahogany plantation or lowland rainforest, coded as 1 and 2.
Topography	Classified as a ridge, valley or slope and coded as 1, 2 and 3, respectively.
Elevation (metres)	Height from mean sea level, measured on a Garmin Etrex 30®.
Slope (°)	Inclination measured from the centre of the plot using a LaserTechnology Inc True Pulse 360°B® rangefinder.
Canopy cover (%)	Estimated crown area directly above the centre of the plot, calibrated with a Panasonic Lumix DMC-FT5® digital camera.
Canopy height (metres)	Measured using a LaserTechnology Inc True Pulse 360°B® rangefinder with the standard height operating procedure.
Percentage of exotic volume	The percentage of exotic tree volume was calculated by dividing exotic tree volume by the total tree volume (native and exotic) in the plot.
Distance to nearest watercourse (metres)	Measured remotely using a Viti Levu watercourse layer.
Distance to nearest forest edge (metres)	Measured remotely using a Viti Levu roads layer and the boundary of Colo-i-Suva Forest Park and Savura Forest Reserve.
Distance to the nearest introduction site (metres)	Measured remotely from the nearest introduction site.

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### S3 - Descriptive statistics

**Table 3. Descriptive statistics (mean, standard deviation and range) of the response and explanatory variables in 90 lowland rainforest and mahogany plantation plots and the results of a Mann-Whitney U test between these two habitats for each variable.**

*P*-values were obtained at a 95% confidence interval ( $p < 0.05$ ).

Variable	Lowland rainforest (n = 57)	Mahogany plantation (n =33)	Mann-Whitney U value, <i>p</i> -value:
	Mean ± Sd, range	Mean ± Sd, range	
Palm clumps	2.51 ± 7.32,	5.06 ± 7.04,	W = 1302,
	0.00 - 43.00	0.00 - 32.00	$p < 0.001$
Palm stems	5.59 ± 14.97,	13.55 ± 24.52,	W = 1298,
	0.00 - 69.00	0.00 - 96.00	$p < 0.001$
Mean stems per clump	1.45 ± 7.24,	1.33 ± 2.12,	W = 1292,
	0.00 - 9.75	0.00 - 9.40	$p < 0.001$
Palm seedlings	23.89 ± 72.96,	62.42 ± 120.53,	W = 1292,
	0.00 - 389.00	0.00 - 613.00	$p = 0.001$
Palm cover	14.14 ± 33.01,	40.00 ± 44.02,	W = 1321,
	0.00 - 100.00	0.00 - 100.00	$p < 0.001$
Tree fern saplings	3.68 ± 3.62,	2.36 ± 4.09,	W = 671
	0.00 - 13.00	0.00 - 16.00	$p = 0.019$
Juvenile tree ferns	1.33 ± 1.73,	1.18 ± 2.39,	W = 779,
	0.00 - 9.00	0.00 - 11.00	$p = 0.14$
Mature tree ferns	2.43 ± 2.21,	1.88 ± 2.15,	W = 761,
	0.00 - 9.00	0.00 - 7.00	$p = 0.13$
Tree fern cover (%)	36.32 ± 28.82,	26.67 ± 29.65,	W = 757,
	0.00 - 90.00	0.00 - 100.00	$p = 0.12$
Min tree fern height	0.47 ± 0.92,	0.22 ± 0.59,	W = 564,
	0.00 - 8.00	0.00 - 3.00	$p = 0.0012$
Max tree fern height	2.96 ± 2.06,	2.11 ± 1.93,	W = 693,
	0.00 - 8.00	0.00 - 8.00	$p = 0.038$
Mean tree fern height	1.96 ± 1.54,	1.49 ± 1.31,	W = 798.7,

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	0.00 - 6.00	0.00 - 5.50	$p = 0.23$
Tree fern volume	$0.06 \pm 0.24,$ 0.00 - 1.79	$0.01 \pm 0.02,$ 0.00 - 0.13	$W = 735,$ $p = 0.085$
Elevation	$173.50 \pm 40.14,$ 79.00 - 267.00	$178.10 \pm 28.35,$ 118.00 - 230.00	$W = 1054,$ $p = 0.35$
Slope	$18.22 \pm 13.36,$ 0.40 - 45.50	$13.12 \pm 14.56,$ 0.00 - 55.00	$W = 713,$ $p = 0.057$
Canopy cover	$56.49 \pm 19.41,$ 20.00 - 90.00	$57.27 \pm 22.54,$ 20.00 - 90.00	$W = 987,$ $p = 0.70$
Canopy height	$22.93 \pm 5.60,$ 12.00 - 37.00	$29.72 \pm 4.39,$ 20.00 - 40.00	$W = 713,$ $p < 0.001$
Percent exotic volume	$12.42 \pm 31.59,$ 0.00 - 100.00	$67.94 \pm 42.65,$ 0.00 - 100.00	$W = 1523.5,$ $p < 0.001$
Distance to watercourse	$55.79 \pm 57.02,$ 1.00 - 241.00	$55.25 \pm 57.72,$ 1.00 - 253.00	$W = 931,$ $p = 0.94$
Distance to nearest forest edge	$136.60 \pm 103.45,$ 5.00 - 432.00	$101.20 \pm 97.07,$ 2.00 - 419.00	$W = 767,$ $p = 0.151$
Distance to nearest introduction	$1632.20 \pm 498.58,$ 576.80 - 2536.80	$1091.40 \pm 713.21,$ 150.70 - 2818.10	$W = 500,$ $p < 0.001$

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#### S4 - Spearman correlation coefficients among explanatory variables

**Table 4. Spearman correlation coefficients ( $\rho$ ) for the explanatory variables measured in 90, 25 m<sup>2</sup> plots surveyed in Colo-i-Suva Forest Park and Savura Forest Reserve, on Viti Levu, Fiji.**

*P*-values were obtained at a 95% confidence interval ( $p < 0.05$ ).

	Elevation	Slope	Canopy height	Canopy cover	Distance to nearest watercourse	Distance to nearest forest edge	Distance to nearest introduction site
Elevation	1	$\rho = -7.2 \times 10^{-3}$ , $p = 0.95$	$\rho = 0.12$ , $p = 0.28$	$\rho = -1.0 \times 10^{-3}$ , $p = 0.86$	$\rho = 0.27$ , $p < 0.001$	$\rho = -2.6 \times 10^{-2}$ , $p = 0.82$	$\rho = -0.35$ , $p < 0.001$
Slope		1	$\rho = -0.11$ , $p = 0.30$	$\rho = 0.14$ , $p = 0.15$	$\rho = 4.5 \times 10^{-2}$ , $p = 0.68$	$\rho = 0.13$ , $p = 0.24$	$\rho = 0.07$ , $p = 0.51$
Canopy height			1	$\rho = -4.9 \times 10^{-2}$ , $p = 0.64$	$\rho = 6.1 \times 10^{-2}$ , $p = 0.57$	$\rho = 4.4 \times 10^{-2}$ , $p = 0.68$	$\rho = -0.46$ , $p = < 0.001$
Canopy cover				1	$\rho = 0.052$ , $p = 0.63$	$\rho = 6.4 \times 10^{-2}$ , $p = 0.55$	$\rho = 0.25$ , $p = 0.02$
Distance to nearest watercourse					1	$\rho = -0.11$ , $p = 0.32$	$\rho = 5.9 \times 10^{-2}$ , $p = 0.58$
Distance to nearest forest edge						1	$\rho = 1.8 \times 10^{-2}$ , $p = 0.87$

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Distance to nearest  
introduction site

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## S5 - Species list of the trees present in the survey

**Table 5. The tree species present with a DBH  $\geq$  0.1 metre in 90, 25 m<sup>2</sup> plots surveyed in Colo-i-Suva Forest Park and Savura Forest Reserve, on Viti Levu, Fiji.**

Genus/Species	Family	Native/Exotic	Count
<i>Agathis macrophylla</i> (Lind.) Mast.	Araucariaceae	Native	1
<i>Albizia</i> sp.	Mimosaceae	Exotic	2
<i>Anacolosa lutea</i> Gillesp.	Olacaceae	Native	1
<i>Atuna racemosa</i> Raf, Sylva Tellur	Chrysobalanaceae	Native	4
<i>Barringtonia</i> spp.	Lecythidaceae	Native	4
<i>Calophyllum vitiense</i> Turrill	Clusiaceae	Native	1
<i>Cerbera</i> sp.	Apocynaceae	Native	2
<i>Crossostylis</i> spp.	Rhizophoraceae	Native	18
<i>Dacrydium nidulum</i> de Laub.	Podocarpaceae	Native	1
<i>Decaspermum vitiense</i> (A. Gray) Niedenzu	Myrtaceae	Native	1
<i>Dillenia biflora</i> (A. Gray) Mertelli ex Dur & Jacks.	Dilleniaceae	Native	7
<i>Dolicholobium</i> sp.	Rubiaceae	Native	1
<i>Dysoxylum richii</i> (A. Gray) C. DC.	Meliaceae	Native	5
<i>Endospermum macrophyllum</i> (Muell. Arg.) Pax & Hoffm.	Euphorbiaceae	Native	1
<i>Eucalyptus</i> sp.	Myrtaceae	Exotic	2
<i>Garcinia myrtifolia</i> A.C. Sm.	Clusiaceae	Native	6
<i>Garcinia pseudoguttifera</i> Seem.	Clusiaceae	Native	2
<i>Geniostoma</i> sp.	Loganiaceae	Native	1
<i>Girroniera celtidifolia</i> Gaud.	Cannabaceae	Native	1
<i>Gnetum gnemon</i> L.	Gnetaceae	Native	7
<i>Gonystylus punctatus</i> A.C. Sm.	Thymelaeaceae	Native	4
<i>Gymnostoma vitiense</i> L.A.S. Johnson.	Casuarinaceae	Native	7
<i>Haplolobus floribundus</i> (C.T. White) Leenh.	Burseraceae	Native	3
<i>Kingiodendron</i> sp.	Caesalpiniaceae	Native	1

Genus/Species	Family	Native/Exotic	Count
<i>Macaranga</i> sp.	Euphorbiaceae	Native	1
<i>Maesopsis eminii</i> Engl.	Rhamnaceae	Exotic	2
<i>Melicope</i> sp.	Rutaceae	Native	1
<i>Myristica</i> spp.	Myristicaceae	Native	19
<i>Neuburgia</i> sp.	Loganiaceae	Native	1
<i>Pagiantha thurstonii</i> (Horne ex Baker) A.C. Sm.	Apocynaceae	Native	1
<i>Pandanus</i> spp.	Pandanaceae	Native	4
<i>Parinari insularum</i> A. Gray	Chrysobalanaceae	Native	1
<i>Pinus radiata</i> D. Don	Pinaceae	Exotic	2
<i>Pinus</i> sp.	Pinaceae	Exotic	2
<i>Spathodea campanulata</i> Beauv.	Bignoniaceae	Exotic	1
<i>Swietenia macrophylla</i> King.	Meliaceae	Exotic	43
<i>Syzygium</i> spp.	Myrtaceae	Native	5
<i>Terminalia</i> sp.	Combretaceae	Native	2
<b>Unknown</b> sp.	Unknown	Exotic	2
<b>Unknown</b> sp. 2	Unknown	Native	1
<i>Veitchia joannis</i> Vietch and H.A. Wendl	Arecaceae	Native	1
<i>Xylopa pacifica</i> A.C. Sm.	Annonaceae	Native	7
Total			179

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## S6 - Summary of the Generalised linear mixed effect model

**Table 6. Parameters for significant explanatory, fixed-effect variables retained in the best generalised linear mixed effect model (GLMM) explaining the abundance of *P. coronata* seedlings in Colo-i-Suva Forest Park and Savura Forest Reserve on Viti Levu, Fiji.**

Habitat type was set as the random effect, but did not explain any variance. Distance = Distance to nearest introduction site. Degrees of freedom = 85.

	<i>F</i> -value	<i>p</i> -value	Coeff.
Intercept	10.02	0.00	5.26
Distance	-7.38	<0.001	$-1.9 \times 10^{-3}$
Canopy cover	-2.29	0.024	$-1.8 \times 10^{-2}$

**Table 7. Parameters for significant explanatory, fixed-effect variables retained in the best model for significant response variables in the best generalised linear mixed effect models (GLMMs) explaining the abundance for three different size classes of tree ferns (saplings, seedling, mature).**

Habitat type was set as the random effect, but did not explain any variance. Degrees of freedom = 85; NS = not significant.

	Saplings			Juveniles			Mature		
	<i>F</i> -value	<i>p</i> -value	Coeff.	<i>F</i> -value	<i>p</i> -value	Coeff.	<i>F</i> -value	<i>p</i> -value	Coeff.
Palm cover	-3.45	<0.001	$-7.9 \times 10^{-3}$	-3.43	<0.001	$-5.7 \times 10^{-3}$	-3.08	0.002	$-5.5 \times 10^{-3}$
Slope	5.82	0.0036	$1.9 \times 10^{-2}$	2.67	0.0075	$1.2 \times 10^{-4}$	NS	NS	NS
Intercept	5.83	<0.001	0.89	4.48	<0.001	0.49	13.20	0.0	1.07