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Pacific Conservation Biology

Supplementary Material

Arboreal activity of invasive rodents: conservation implications for the control of an island pest

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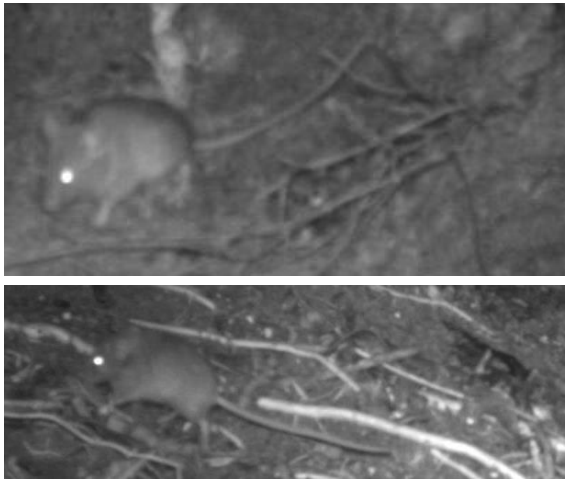
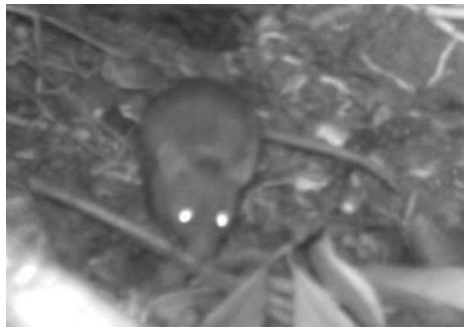
Supplementary tables and figures supplied in this appendix include: identification guide for Norfolk Island rodent species based on camera trap imagery (Table S1); model selection metrics for candidate distance sampling models (Table S2); estimated regression parameters, standard errors and 95% credible intervals for continuous rodent activity indices for three monitoring methods (Table S3); anecdotal evidence of arboreal rodent foraging and dwelling (Table S4); rodent bait station network in Norfolk Island National Park (Figure S1); continuous rodent activity indices across forest strata and forest type for three monitoring methods (Figure S2); comparison of rodent density estimates derived from thermal surveys and model estimates of continuous activity indices for three monitoring methods (Figure S3); and distance sampling detection curves including seasonal variation in rodent detectability (Figure S4).

Table S1: Norfolk Island rodent identification guide. The features presented here were used to distinguish between black rats (*Rattus rattus*), Pacific rats (*Rattus exulans*) and house mice (*Mus musculus*) on Norfolk Island. Depending on location and species present, some these features may be shared with other murid rodent species. Weight ranges from Menkhorst and Knight (2011).

	Black rat - *Rattus rattus*	**Pacific rat – *Rattus exulans***	**House mouse – *Mus musculus***
Size	95-300g	35-100g	10-25g
Tail	Thick and heavy; much longer than head-body	Finer than *R. rattus*; slightly longer then head-body	Thin, slightly longer than head-body
Nose	Longer	Shorter	Pointy
Ears	Larger, would reach eyes if folded down	Smaller, would not reach eyes if folded down	Large
General appearance	Shaggy fur, guard hairs often visible	Relatively short fur with a 'soft' appearance owing to indistinct guard hairs	Relatively sleek fur; substantially smaller, with finer features than *Rattus*
			








Menkhorst P, Knight F (2011). ‘Field Guide to the Mammals of Australia’ 3rd ed. (Oxford University Press: South Melbourne)

Table S2 Model selection metrics for candidate distance sampling models ranked by ΔAIC. Possible covariates included seasons (spring 2019, autumn 2020), forest type (guava, hardwood, palm), site visit (1:3), and rodent detection height off the ground scaled (-1.35: 3.27). Other covariates initially tested included observer (AHN, KG, NW, JR) and hours after sunset (1:5), though all models including these covariates returned poor goodness of fit results ($p < 0.01$) so were not selected as candidate models.

Model covariates	**df**	**AIC**	**ΔAIC**
season	3	1621.3	0.0
forest type + site visit + scaled(height) + season	8	1623.2	1.9
scaled(height)	3	1627.4	6.0
site visit	4	1628.4	7.1
forest type + site visit + scaled(height)	7	1629.0	7.6
forest type	4	1825.2	203.9
No covariates included	2	1831.8	210.5

Table S3 Estimated regression parameters, standard errors and 95% credible intervals for a) zero inflated (zi) Poisson GLMM predicting rodent activity as measured by camera traps; b) beta GLMM predicting rodent activity as measured by chew cards; c) beta GLMM predicting rodent activity as measured by tracking tunnels.

a)	*Rodent active nights (Camera traps)*			
	Estimate	**Std. error**	**2.5%**	**97.5%**
Intercept	1.971	0.190	1.599	2.344
ForestHardwood	-0.213	0.264	-0.730	0.303
ForestPalm	0.073	0.261	-0.439	0.584
StrataMid-storey	0.233	0.073	0.089	0.376
StrataCanopy	0.104	0.075	-0.043	0.250
zi Intercept	-1.107	0.184	-1.467	-0.747
b)	*Proportion area chewed (Chew cards)*			
	Estimate	**Std. error**	**2.5%**	**97.5%**
Intercept	-0.253	0.415	-1.067	0.560
ForestHardwood	-0.658	0.537	-1.710	0.393
ForestPalm	0.265	0.533	-0.779	1.310
StrataMid-storey	0.318	0.243	-0.158	0.794
StrataCanopy	0.450	0.239	-0.018	0.919
c)	*Proportion card tracked (Tracking tunnels)*			
	Estimate	**Std. error**	**2.5%**	**97.5%**
Intercept	-0.430	0.472	-1.356	0.496
ForestHardwood	-0.633	0.497	-1.607	0.341
ForestPalm	-0.224	0.496	-1.196	0.749
StrataMid-storey	0.358	0.202	-0.038	0.755
StrataCanopy	0.135	0.203	-0.262	0.533

Table S4 Anecdotal evidence of invasive rodent foraging and dwelling observed upon collection of above-ground rodent monitoring stations across three forest types, Norfolk Island National Park. Data was collected over two month-long observation periods in the austral spring 2019 and austral autumn 2020. Height refers to the deployment height of the monitoring station.

Season	**Forest type (site #)**	**Strata**	**Height (m)**	**Evidence of rodent foraging and/or dwelling**

Spring	Guava (01)	Canopy	7.2	Rodent faecal pellets and pine kernels inside tracking tunnel
Spring	Guava (10)	Canopy	6.3	Denning materials completing filling tracking tunnel, including African olive (*Olea europaea*) leaves and twigs, clumps of lichen
Autumn	Hardwood (07)	Canopy	8.5	White oak (*Lagunaria patersonia*) fruit with rodent teeth marks found in a small depression near the tracking tunnel
Autumn	Palm (01)	Mid-storey	3.7	Pittosporum (*Pittosporum bracteolatum*) fruit with rodent teeth marks found in a small depression near the camera trap
Autumn	Palm (07)	Canopy	9.8	Indeterminate seed husks and rodent faecal pellets inside tracking tunnel
Autumn	Palm (08)	Canopy	8.6	Niau palm (*Rhopalostylis baueri*) husks and cherry guava (*Psidium cattleyanum*) fruit inside tracking tunnel

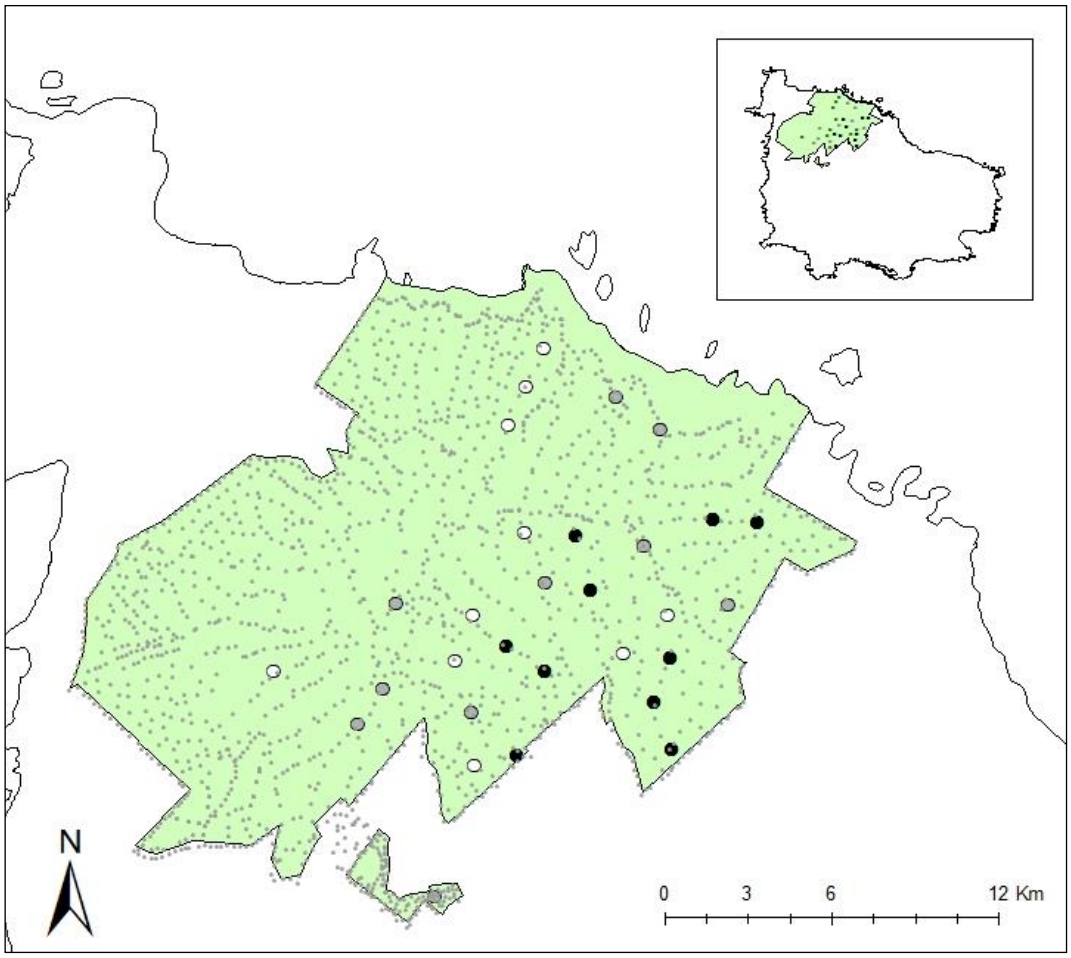


Figure S1 Rodent control network in the Norfolk Island National Park. Grey points represent individual bait stations or tunnels that are periodically refreshed with rodenticide feed blocks. Coloured points represent site locations for the present study coloured by forest type: invasive cherry guava forest (red), native hardwood forest (blue) and native palm forest (green).

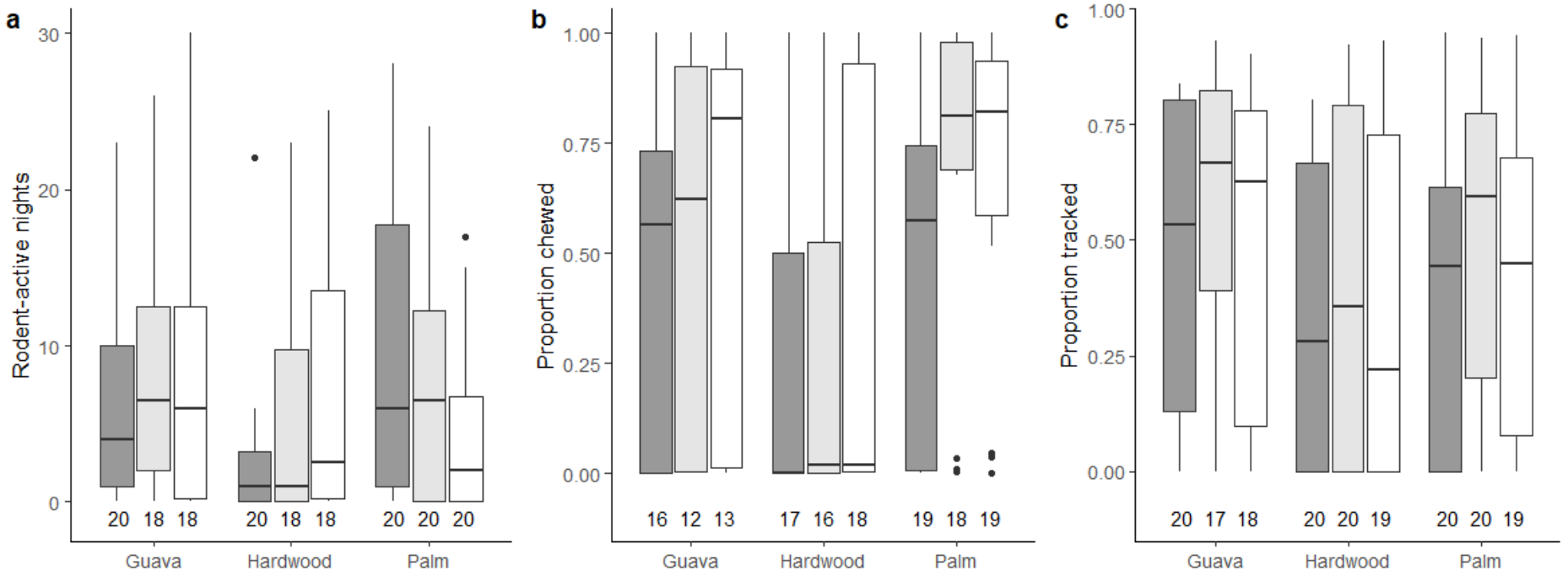


Figure S2 Invasive rodent activity across three forest strata: ground (dark grey), mid-storey (light grey) and canopy (white) grouped by common forest type (Invasive guava, native hardwood and native palm) in the Norfolk Island National Park. Activity was measured using three different monitoring methods: camera traps (a), chew cards (b), and tracking tunnels (c). Data was collected over continuous one-month observation periods across two seasons in 2019 and 2020. Samples retained per treatment after the removal of failed cameras, dislodged chew cards and damaged tracking tunnels are reported below each box. Neither predictor (strata and forest type) nor the interaction term had a significant effect on any rodent activity index, and no pair-wise comparisons were significantly different. Lines inside boxes indicates median activity values, lower and upper box boundaries indicate 25th and 75th percentiles respectively, lower and upper error bars indicate 95% confidence intervals. Black points indicate outliers.

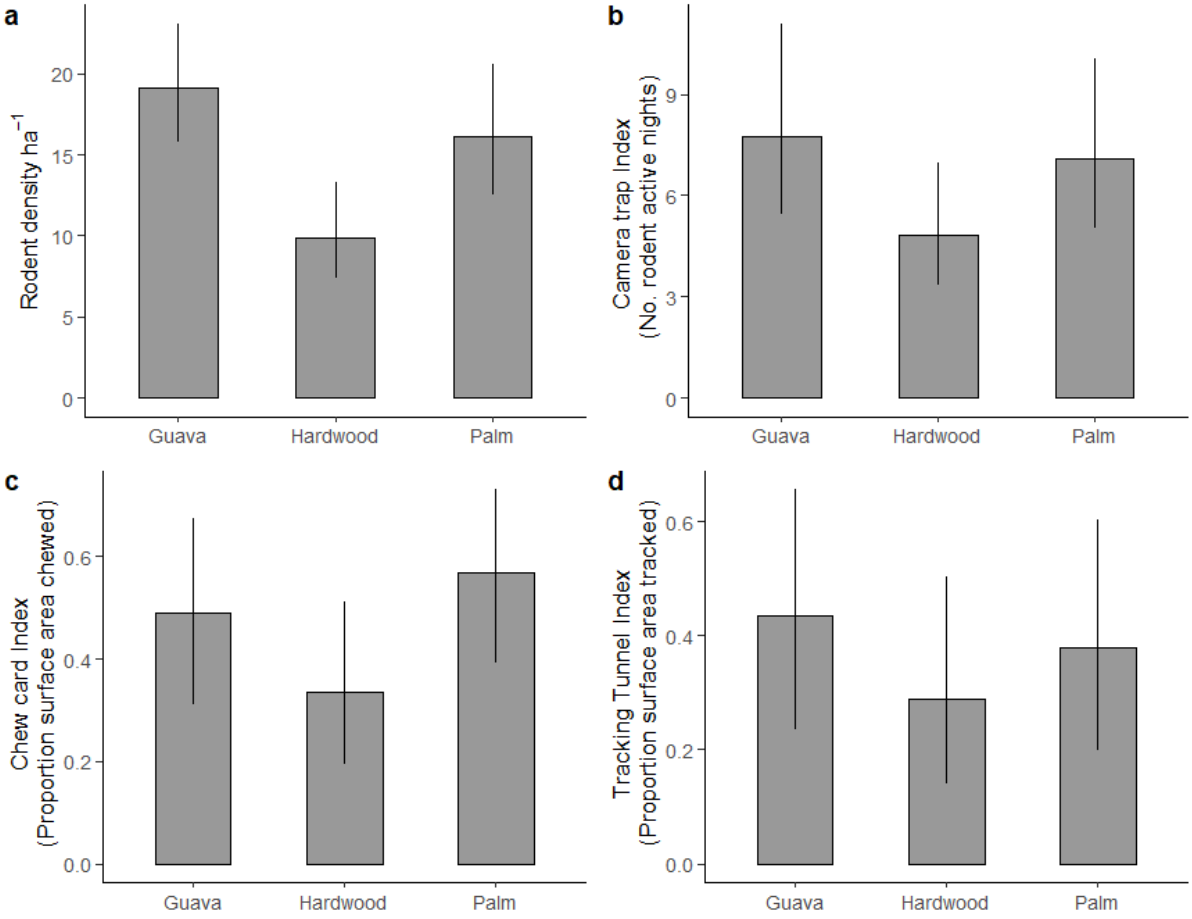


Figure S3 Comparison of rodent density estimates derived from thermal surveys (a) and model estimates of activity indices calculated from camera trap (b), chew card (c), and tracking tunnel (d) data for three forest types in the Norfolk Island National Park. Density estimates (a) and confidence intervals were calculated using distance sampling, and activity index model estimates and confidence intervals were generated from a negative binomial GLM for camera traps (b), and beta regression GLMMs for chew cards (c) and tracking tunnels (d). Error bars indicate upper and lower 95% CI.

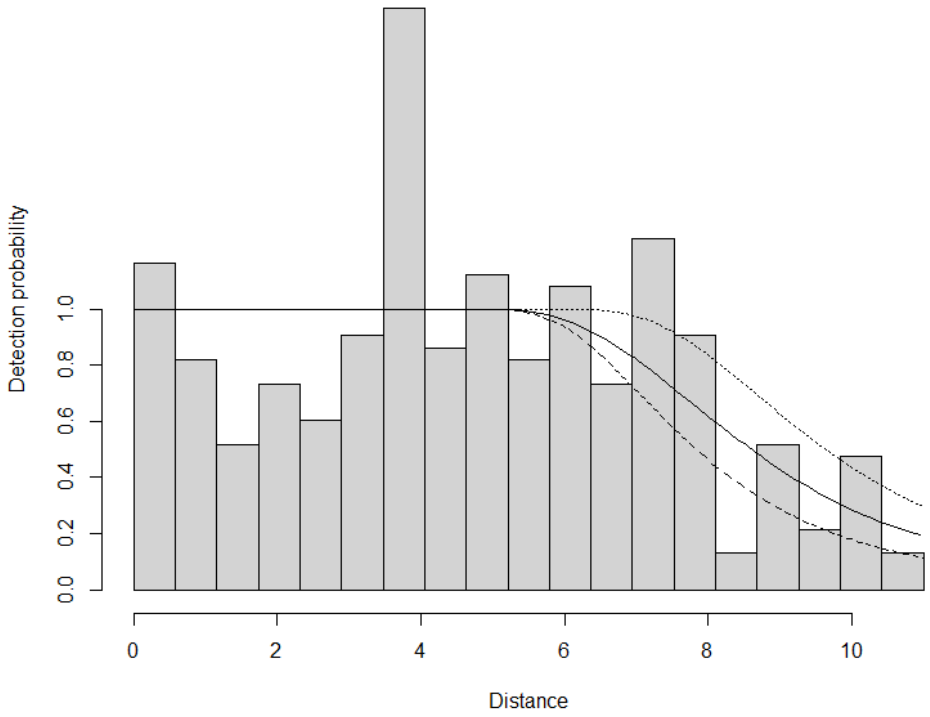


Figure S4 Rodent detection probability as a function of distance (m) (solid line) during distance sampling thermal imaging surveys in Norfolk Island National Park; detectability in the austral spring (long dashed line) was lower than detectability in the austral autumn (short dashed line). Bars indicate the number of rodent observations made per distance increment.