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Wildlife Research

Supplementary Material

Investigating the impact of black rats (*Rattus rattus*) on the endemic and threatened avifauna of Christmas Island

Rosalie Willacy^{A,}, Samantha Flakus^B, Eve McDonald-Madden^A, and Sarah Legge^{A,C}*

^ASchool of Earth and Environmental Sciences, The University of Queensland, St Lucia, Qld 4072, Australia.

^BParks Australia, Christmas Island, WA 6798, Australia.

^CResearch Institute of Environment and Livelihoods, Charles Darwin University, Casuarina, NT 0810, Australia.

*Correspondence to: Rosalie Willacy School of Earth and Environmental Sciences, The University of Queensland, St Lucia, Qld 4072, Australia Email: Rosalie.willacy@gmail.com

Supplementary material

Table S1 Motion camera details used for nest monitoring

Cameras and settings

Camera settings	
Camera type	Ltl Acorn 3510, wide angle lens
Batteries	8x Powerex Nickel Metal Hydride
Battery charger	Maha Powerex MH-C980
Photos	Three per trigger, consecutive
Sensitivity	High
Red-tailed tropicbird specific settings	
Trigger interval	15 mins
Daily start time	1500
Daily end time	0900

To conserve battery life and memory and to reduce the number of false positives (i.e. particularly from bird preening and other movement) for red-tailed tropicbirds, cameras were set to take three stills per trigger between the hours of 3pm and 9am. This is likely to be the most active period for rats, however some predation events, particularly involving goshawks and cats may have been missed using this schedule. The cameras were also set with a 15 minute down time interval between triggers to reduce the number of false triggers. The camera sensitivity was set to highest to reduce false negatives, as the infrared sensor can be less effective in humid environments (this was observed using Reconyx cameras that sometimes didn't trigger during high humidity periods i.e. in the early hours of the morning), and because the body temperature of animals on Christmas Island (especially ground nesting seabirds and their nests on rocky substrates) are relatively close to the ambient background temperature. Camera trapping success benefited from the use of silica gel sachets inside cameras, Coopex residual insecticide to deter ants, the use of bungy cords to secure cameras to trees or limestone pinnacles, and frequent checks (three weeks to one month) to replace batteries and clean spider webs and seabird droppings from the camera lenses. Cameras were largely unaffected by Robber (*Birgus latro*) and red crabs (*Gecarcoidea natalis*). This study also

benefited greatly from the use of an extension selfie-stick and videos of nest contents recorded by a smartphone mounted on the stick, to check thrush nest status without damaging nests.

Table S2 Forest bird abundance models

The most parsimonious mixed effect linear models of bird abundance as a function of temporal, habitat, microhabitat and biotic variables ($\Delta AIC < 2$)

Model terms	K	AICc	$\Delta AICc$	AICcWt	LL
Thrush					
Shannon's diversity index (vegetation) + Yellow crazy ant super colony + FPC + Habitat + Leaf litter + Tree density	11	1207.45	0.00	0.16	-592.04
Shannon's diversity index (vegetation) + Yellow crazy ant abundance + Habitat + Leaf litter + Shrub height + Tree density	10	1207.68	0.24	0.14	-593.28
Shannon's diversity index (vegetation) + Yellow crazy ant abundance + FPC + Habitat + Leaf litter + Shrub height + Tree density	11	1208.31	0.86	0.10	-592.47
Shannon's diversity index (vegetation) + Yellow crazy ant super colony + FPC + Habitat + Leaf litter + Season + Tree density	12	1208.50	1.05	0.09	-591.44
Shannon's diversity index (vegetation) + Yellow crazy ant super colony + Yellow crazy ant abundance + FPC + Habitat + Leaf litter + Tree density	12	1208.73	1.28	0.08	-591.56
FPC + Tree density	5	1208.79	1.35	0.08	-599.25
Shannon's diversity index (vegetation) + Yellow crazy ant abundance + Habitat + Leaf litter + Season + Shrub height + Tree density	11	1208.85	1.41	0.08	-592.75
Shannon's diversity index (vegetation) + Yellow crazy ant abundance + FPC + Habitat + Leaf litter + Tree density	10	1209.01	1.56	0.07	-593.94
FPC	4	1209.30	1.85	0.06	-600.55
Shannon's diversity index (vegetation) + Yellow crazy ant super colony + FPC + Habitat + Leaf litter + Shrub height + Tree density	12	1209.38	1.94	0.06	-591.88
Shannon's diversity index (vegetation) + Yellow crazy ant abundance + FPC + Habitat + Leaf litter + Season + Shrub height + Tree density	12	1209.41	1.97	0.06	-591.90
White-eye					
Yellow crazy ant super colony + Leaf litter + Season + Shrub density + Tree density	9	1939.18	0.00	0.11	-960.13
Yellow crazy ant super colony + Leaf litter + Season + Tree density	8	1939.36	0.19	0.10	-961.32
Yellow crazy ant super colony + Leaf litter + Season + Shrub height + Tree density	9	1939.49	0.31	0.10	-960.29
Yellow crazy ant super colony + Leaf litter + Season + Shrub density	8	1939.64	0.46	0.09	-961.45
Yellow crazy ant super colony + Leaf litter + Rat abundance + Season + Shrub density	9	1940.07	0.89	0.07	-960.58
Shannon's diversity index (vegetation) + Yellow crazy ant super colony + Leaf litter + Season + Shrub height + Tree density	10	1940.20	1.02	0.07	-959.54
Yellow crazy ant super colony + Leaf litter + Rat abundance + Season + Shrub height + Tree density	10	1940.24	1.06	0.07	-959.55
Yellow crazy ant super colony + Leaf litter + Season + Shrub height + Shrub density + Tree density	10	1940.32	1.14	0.06	-959.59
Shannon's diversity index (vegetation) + Yellow crazy ant super colony + Leaf litter + Season + Shrub density + Tree density	10	1940.42	1.24	0.06	-959.65
Shannon's diversity index (vegetation) + Yellow crazy ant super colony + Leaf litter + Season + Tree density	9	1940.58	1.40	0.06	-960.83
Shannon's diversity index (vegetation) + Yellow crazy ant super colony + Leaf litter + Season + Shrub density	9	1940.66	1.49	0.05	-960.87
Yellow crazy ant super colony + Leaf litter + Season	7	1940.78	1.60	0.05	-963.11
Yellow crazy ant super colony + Leaf litter + Rat abundance + Season + Shrub	10	1940.85	1.68	0.05	-959.86

density + Tree density					
Yellow crazy ant super colony + Leaf litter + Rat abundance + Season + Shrub height + Shrub density + Tree density	11	1941.00	1.83	0.05	-958.82
Emerald Dove					
FPC + Leaf litter + Season + Tree density	6	224.05	0.00	0.33	-105.81
FPC + Leaf litter + Season + Shrub density + Tree density	7	224.60	0.56	0.25	-105.02
FPC + Leaf litter + Rat abundance + Season + Tree density	7	225.61	1.57	0.15	-105.52
FPC + Leaf litter + Season + Shrub height + Tree density	7	225.93	1.88	0.13	-105.68
Yellow crazy ant super colony + FPC + Leaf litter + Season + Tree density	7	225.93	1.88	0.13	-105.68
Imperial Pigeon					
Canopy height + Season + Tree density	7	1299.75	0.73	0.16	-642.59
Shannon's diversity index + Canopy height + Season + Tree density	7	1299.78	0.77	0.16	-642.61
Yellow crazy ant abundance + Canopy height + Season + Tree density	8	1300.44	1.43	0.12	-641.86
Yellow crazy ant super colony + Canopy height + Season + Tree density	8	1300.53	1.51	0.11	-641.90
Shannon's diversity index + Yellow crazy ant abundance + Canopy height + Season + Tree density	7	1300.62	1.61	0.11	-643.03
Canopy height + Rat relative abundance + Season + Tree density	9	1300.73	1.72	0.10	-640.91
Shannon's diversity index + Yellow crazy ant super colony + Canopy height + Season + Tree density	6	1299.01	0.00	0.24	-643.30

Table S3 Model summaries for forest bird abundance

Generalised linear mixed model coefficients for thrush, white-eye, emerald dove and imperial pigeon abundances as a function of covariates. All error distributions were normal except for the emerald dove for which a binomial error distribution with a log link function was used. Reference levels for categorical predictors are Yellow crazy ant super colony absent, Coastal habitat and Dry season.

Thrush averaged coefficients (full average)					
	Estimate	Std. Error	AdjustedSE	z value	Pr(z)
Intercept	5.54	2.42	2.42	2.28	0.02*
Shannon's diversity index	-1.52	0.91	0.91	1.67	0.10
Yellow crazy ant super colony nearby	1.09	1.47	1.47	0.74	0.46
Yellow crazy ant super colony present	2.55	3.39	3.39	0.75	0.45
FPC	-1.33	1.00	1.01	1.32	0.19
Disturbed habitat	6.27	3.53	3.54	1.77	0.08
Rainforest habitat	5.20	2.91	2.92	1.78	0.08
Leaf litter	-1.28	0.74	0.75	1.72	0.09
Tree density	1.54	0.76	0.76	2.03	0.04*
Yellow crazy ant abundance	0.47	0.58	0.58	0.81	0.42
Shrub height	0.34	0.52	0.52	0.65	0.51

Wet season	0.12	0.37	0.37	0.33	0.74
White-eye averaged coefficients (full average)					
	Estimate	Std. Error	AdjustedSE	z value	Pr(z)
Intercept	61.08	3.25	3.27	18.69	0.00*
Yellow crazy ant super colony nearby	-8.82	5.50	5.53	1.60	0.11
Yellow crazy ant super colony present	29.20	8.30	8.34	3.50	0.00*
Leaf litter	-11.65	2.36	2.37	4.91	0.00*
Wet Season	-10.90	3.78	3.80	2.87	0.00*
Shrub density	1.86	2.44	2.44	0.76	0.45
Tree density	3.29	2.95	2.96	1.11	0.27
Shrub height	1.22	2.27	2.27	0.54	0.59
Rat abundance	-0.48	1.46	1.46	0.33	0.74
Shannon's diversity index	-0.61	1.48	1.49	0.41	0.68
Emerald dove averaged coefficients (full average)					
	Estimate	Std. Error	AdjustedSE	z value	Pr(z)
Intercept	1.47	0.24	0.24	6.14	0.00*
FPC	-0.83	0.25	0.25	3.34	0.00*
Leaf litter	0.62	0.23	0.23	2.72	0.01*
Wet Season	-0.84	0.35	0.35	2.39	0.02*
Tree density	0.86	0.25	0.25	3.37	0.00*
Shrub density	-0.08	0.17	0.17	0.47	0.64
Rat abundance	0.03	0.10	0.10	0.26	0.79
Shrub height	-0.02	0.09	0.09	0.18	0.86
Imperial pigeon averaged coefficients (full average)					
	Estimate	Std. Error	AdjustedSE	z value	Pr(z)
Intercept	11.09	0.74	0.75	14.88	0.00*
Canopy height	4.16	0.71	0.71	5.83	0.00*
Wet season	2.48	0.77	0.78	3.19	0.00*
Tree density	-1.65	0.71	0.71	2.32	0.02*
Shannon's diversity index	0.25	0.53	0.54	0.47	0.64
Yellow crazy ant abundance	-0.24	0.51	0.51	0.47	0.64
Yellow crazy ant super colony nearby	0.14	0.63	0.63	0.23	0.82
Yellow crazy ant super colony present	-0.42	1.36	1.37	0.30	0.76
Rat abundance	0.07	0.32	0.32	0.21	0.84

Table S4 Thrush descriptive breeding behaviour data

Thrush nests found in a large range of shrub and rainforest tree species. The majority of nests found were associated with tree forks, hollows or Bird's nest ferns (*Asplenium nidus*), as well as palm (*Arenga listeri*) fronds, Pandanus (*Pandanus sp.*) leaves and within the aerial roots of Fig trees (*Ficus microcarpa*) from 2m to 10m (average 4.35m). Thrush laid between one and four eggs, but median

clutch sizes were 2, and average clutch sizes was 1.72. The average incubation time from egg laying to hatching was 11.57 days (n=7 individuals), while the average time from hatching to fledging was 13.17 days (n=29 individuals). For nests that were observed from the point of egg laying to fledging, the average time from egg lay to fledge was 25.83 days (n=6, range 24 – 27 days).

Tree species on Christmas Island in which thrush nests were located. Nests were predominately found in three species (*Arenga listeri*, *Ficus microcarpa* and *Pandanus christmatensis*).

Tree species	No. of nests
<i>Arenga listeri</i>	13
<i>Barringtonia racemosa</i>	6
<i>Celtis</i>	1
<i>Cerbera manghas</i>	2
Dead stag	3
False curry leaf	2
<i>Ficus microcarpa</i>	14
<i>Ficus saxophila</i>	1
<i>Guettarda speciosa</i>	1
<i>Hernandia ovigera</i>	1
Hibiscus	1
<i>Inocarpus fagifer</i>	10
<i>Lucaena leucocephala</i>	3
Macaranga	1
<i>Maclura</i> and <i>Ochrosia</i>	1
<i>Morinda citrifolia</i>	2
<i>Ochrosia ackeringae</i>	4
<i>Pandanus christmatensis</i>	16
<i>Pandanus elatus</i>	1
<i>Pittosporum</i>	1
<i>Planchonella nitida</i>	2
Sapling, unknown	1
<i>Terminalia catappa</i>	2
Unknown	2

Table S5 Model summaries for nest success

Generalised linear top model coefficients for thrush and red-tailed tropicbird nest success a) where rat abundance was measured at the site level and b) using a subset of the data (2018 only) and rat

activity measured at the nest. Reference levels for categorical predictors are Year 2017 and Site – Daniel Roux.

Thrush					
	Estimate	Std.Error	AdjustedSE	zvalue	Pr(z)
Intercept	-1.44	0.51	NA	-2.77	0.005
Rat density	0.07	0.03	NA	2.32	0.02*
Red-tailed tropicbird model a) site					
	Estimate	Std.Error	AdjustedSE	zvalue	Pr(z)
Intercept	0.048	0.047	0.048	0.100	0.920
Site – Settlement	-0.25	0.55	0.56	0.45	0.64
Site – Smiths Pt	1.25	0.64	0.65	1.91	0.05
Year - 2018	-0.08	0.28	0.28	0.304	0.76
Red-tailed tropicbird model b) nest					
	Estimate	Std.Error	AdjustedSE	zvalue	Pr(z)
Intercept	0.78	0.43	NA	1.83	0.06
Rat activity at nest	-0.69	0.38	NA	-1.8	0.07