Supplementary Material

Appendix S1. Distance between sanctuary sites and non-treatment sites.

Sanctuary name	Distance to non-treatment site (km)
Orokonui Ecosanctuary	< 3
Sanctuary Mountain Maungatautari	35
Boundary Stream MI	6
Rotoiti Nature Recovery Project	20
Halfmoon Bay Habitat Restoration Project	3–5
East Harbour Regional Park MI	< 3
Totara Reserve	7
Wainuiomata MI	< 1

Appendix S2. Summary of kererū nesting studies used in literature review.

Site	Reference	Proportion success	Total nests	Successful	Unsuccessful
Unmanaged					
Pelorus Bridge (1983–1991)	Clout et al. 1995a	0.22	45	10	35
Mohi Bush (1988–1991)	Clout et al. 1995a	0.00	9	0	9
Wenderholm (1988–1990)	Clout et al. 1995a	0.00	20	0	20
Wenderholm (1990–1992)	Clout et al. 1995b	0.00	7	0	7
Schischka's Farm (1993–1995) (near Wenderholm)	James & Clout 1996	0.13	32	4	28
Motatau Forest (1996–1997)	Innes et al. 2004	0.00	13	0	13
Maungatapere (1991–1993)	Pierce & Graham 1995	0.19	31	6	25
Whirinaki Forest Park (1998–1999)	Powlesland et al. 2003	0.25	8	2	6
Banks Peninsula (2004–2005)	Schotborgh 2005	0.35	20	7	13
Banks Peninsula (2004–2005)	Prendergast et al. 2006	0.39	18	7	11
Banks Peninsula (2005–2006)	Campbell et al. 2008	0.17	12	2	10
Southland (2003–2006)	R. Powlesland (DOC unpublished data)	0.35	34	12	22
Taranaki (2003–2006)	R. Powlesland (DOC unpublished data)	0.39	54	21	33
Rat control					
Wenderholm (1992–1993)	Clout et al. 1995b	0.45	11	5	6
Wenderholm (1993–1995)	James & Clout 1996	0.26	38	10	28
Motatau (1997–1998)	Innes et al. 2004	0.25	4	1	3
Possum control					
Motatau (1999–2000)	Innes et al. 2004	0.25	4	1	3
Motatau (2000–2001)	Innes et al. 2004	0.31	16	5	11
Rat and possum control					
Whirinaki Forest Park (2001–2002)	Powlesland et al. 2003	0.79	14	11	3
Motatau (1998–1999)	Innes et al. 2004	1.00	7	7	0

Appendix S3. Parameter estimates and standard errors from a generalised linear mixed effect model (with binomial error) of nesting success of kererū. Estimates and standard error are expressed on the logit scale of the link function.

Variable (Management)	Estimate	Standard Error	z value	P
No management	−1.482	0.291	−5.095	< 0.001
Rat control	1.408	0.649	2.169	0.030
Possum control	1.052	0.747	1.409	0.159
Rat and possum control	3.606	0.803	4.488	< 0.001

Appendix S4. Details of results from survival studies.

Source	Site	Predation	Starvation	Poor condition and/or disease	Hunting	Impact injury	Electrocution	Other	Unknown	Total number of kererū found dead
Powlesland et al. 2003	Whirinaki Forest Park (1998-2002)	39	0	1	4	0	0	0	8	52
Clout et al. 1995b	Pelorus Bridge (1983-1991)	6	0	0	0	2	0	0	2	10
Clout et al. 1995b	Mohi Bush (1988-1991)	1	6	0	0	0	0	0	1	8
Clout et al. 1995b	Wenderholm (1988-1990)	1	0	0	2	0	0	0	0	3
R. Powlesland (pers. comm.)	Taranaki (2003-2006)	2	0	1	0	6	1	0	5	15
R. Powlesland (pers. comm.)	Southland (2003-2006)	1	0	0	0	11	5	3	10	30
Prendergast et al. 2006	Banks Peninsula (2004-2005)	9	0	0	0	1	0	0	1	11
Gill 2006	Auckland	2	0	0	2	30	0	1	73	108

Appendix S5. Parameter estimates for models of kererū local occupancy. Parameter estimates from the 'all of New Zealand' linear mixed effects models of probabilities of occupancy for kererū in 2,155 10 × 10 km squares across New Zealand. Estimates are parameter estimates and are shown on the logit scale of the data. Lower and upper bounds of 95% confidence intervals from 1000 models, which are replicated fits of the best model each using a different draw from the posterior distribution of local occupancy estimates for each species (Walker & Monks 2018). We consider that there is strong support for an effect (i.e. it is statistically significant) when the 95% confidence intervals of parameter estimates exclude zero. Time indicates a contrast between the second (1999–2004) and the first (1969–1979) measurement periods; bs(Forest cover)1, bs(Forest cover)2, and bs(Forest cover)3 are the three terms of the cubic spline function of percent indigenous forest cover; Temperature is median mean annual temperature across land in the square. Road density refers to relative road density, which was calculated as the length of all roads contained in the LINZ 1:250k road centrelines 2011 data set divided by land area in the square and transformed by taking the square root. Island refers to either the North or South Island (the latter also including Stewart Island/Rakiura) of New Zealand. Colons refer to interaction terms between predictors.

Term	Estimate	Lower 95% CL	Upper 95% CL
Intercept	−0.79	−1.16	−0.38
Time	1.25	0.74	1.74
bs(Forest cover)1	1.56	0.58	2.74
bs(Forest cover)2	−0.71	−1.52	0.09
bs(Forest cover)3	1.48	0.66	2.30
Road density	−0.03	−0.35	0.33
Temperature	−1.01	−1.40	−0.64
Island	−0.20	−0.45	0.03
Time:bs(Forest cover)1	−3.02	−4.53	−1.56
Time:bs(Forest cover)2	2.21	1.04	3.41
Time:bs(Forest cover)3	−0.66	−1.82	0.49
Time:Road density	−0.39	−0.86	0.09
bs(Forest cover)1:Road density	−1.36	−2.35	−0.30
bs(Forest cover)2:Road density	1.18	0.40	2.04
bs(Forest cover)3:Road density	−0.67	−1.28	−0.03
Time:Temperature	−0.05	−0.59	0.43
bs(Forest cover)1:Temperature	2.65	1.35	4.03
bs(Forest cover)2:Temperature	−1.48	−2.82	−0.12
bs(Forest cover)3:Temperature	−0.32	−1.74	1.00
Road density:Temperature	−0.10	−0.43	0.27
Time:Island	−0.81	−1.10	−0.47
bs(Forest cover)1:Island	0.35	−0.41	1.03
bs(Forest cover)2:Island	0.86	0.37	1.37
bs(Forest cover)3:Island	0.40	−0.10	0.93
Road density:Island	0.01	−0.19	0.20
Temperature:Island	0.58	0.34	0.83
Time:bs(Forest cover)1:Road density	2.11	0.62	3.68
Time:bs(Forest cover)2:Road density	−0.32	−1.55	0.95
Time:bs(Forest cover)3:Road density	1.09	0.14	1.94
Time:bs(Forest cover)1:Temperature	−0.74	−2.60	1.00
Time:bs(Forest cover)2:Temperature	−1.51	−3.40	0.35
Time:bs(Forest cover)3:Temperature	1.75	−0.22	3.74
Time:Road density:Temperature	0.09	−0.41	0.52
bs(Forest cover)1:Road density:Temperature	0.00	−1.07	1.08
bs(Forest cover)2:Road density:Temperature	−1.89	−2.90	−0.86
bs(Forest cover)3:Road density:Temperature	−0.61	−1.60	0.33
Time:bs(Forest cover)1:Island	1.71	0.76	2.66
Time:bs(Forest cover)2:Island	−1.54	−2.26	−0.81
Time:bs(Forest cover)3:Island	−0.14	−0.85	0.61
Time:Road density:Island	0.25	−0.01	0.53
bs(Forest cover)1:Road density:Island	1.33	0.64	1.97
bs(Forest cover)2:Road density:Island	−1.39	−1.99	−0.87
bs(Forest cover)3:Road density:Island	0.62	0.20	1.02
Time:Temperature:Island	0.00	−0.32	0.34
bs(Forest cover)1:Temperature:Island	−0.92	−1.89	−0.06
bs(Forest cover)2:Temperature:Island	0.68	−0.22	1.58
bs(Forest cover)3:Temperature:Island	0.96	0.15	1.89
Road density:Temperature:Island	0.07	−0.15	0.24
Time:bs(Forest cover)1:Road density:Temperature	1.04	−0.51	2.66
Time:bs(Forest cover)2:Road density:Temperature	−0.98	−2.50	0.43
Time:bs(Forest cover)3:Road density:Temperature	0.97	−0.44	2.40
Time:bs(Forest cover)1:Road density:Island	−1.49	−2.41	−0.61
Time:bs(Forest cover)2:Road density:Island	0.45	−0.33	1.29
Time:bs(Forest cover)3:Road density:Island	−0.77	−1.29	−0.20

Appendix S5. Continued.

| Term	Estimate	Lower 95% CL	Upper 95% CL
Time:bs(Forest cover)1:Temperature:Island	0.47	−0.70	1.71
Time:bs(Forest cover)2:Temperature:Island	0.75	−0.43	1.98
Time:bs(Forest cover)3:Temperature:Island	−1.36	−2.66	−0.04
Time:Road density:Temperature:Island	−0.05	−0.28	0.24
bs(Forest cover)1:Road density:Temperature:Island	0.50	−0.17	1.22
bs(Forest cover)2:Road density:Temperature:Island	0.41	−0.27	1.01
bs(Forest cover)3:Road density:Temperature:Island	0.89	0.34	1.58
Time:bs(Forest cover)1:Road density:Temperature:Island	−0.83	−1.83	0.09
Time:bs(Forest cover)2:Road density:Temperature:Island	0.79	−0.06	1.74
Time:bs(Forest cover)3:Road density:Temperature:Island	−0.81	−1.75	0.08

Appendix S6. Parameter estimates from the New Zealand forests linear mixed effects models of probabilities of occupancy for kererū in 2155 10 × 10 km squares across New Zealand. Estimates are parameter estimates and are shown on the logit scale of the data. Lower and upper bounds of 95% confidence intervals from 1000 models, which are replicated fits of the best model each using a different draw from the posterior distribution of local occupancy estimates for each species (Walker & Monks 2018). We consider that there is strong support for an effect (i.e. it is statistically significant) when the 95% confidence intervals of parameter estimates exclude zero. Time indicates a contrast between the second (1999–2004) and the first (1969–1979) measurement periods; bs(Pod/bl prop.)1 to 3 are the three terms of the cubic spline function of the proportion of indigenous forest cover in a forest class dominated by podocarp or broadleaved trees; Forest cover is the percent indigenous forest cover across the square; Temperature is median mean annual temperature across land in the square. Island refers to either the North or South Island (the latter also including Stewart Island/Rakiura) of New Zealand. Colons refer to interaction terms between predictors.

Term	Estimate	Lower 95% CL	Upper 95% CL
Intercept	−0.55	−1.08	0.03
Time	0.96	0.17	1.70
bs(Pod/bl prop.)1	1.55	0.12	3.30
bs(Pod/bl prop.)2	−0.62	−1.74	0.44
bs(Pod/bl prop.)3	1.12	0.42	1.81
Temperature	−0.25	−0.81	0.32
Island	0.26	−0.06	0.55
Forest cover	2.27	1.17	3.37
Time:bs(Pod/bl prop.)1	−0.67	−2.95	1.56
Time:bs(Pod/bl prop.)2	1.70	0.00	3.31
Time:bs(Pod/bl prop.)3	−0.43	−1.40	0.56
Time:Temperature	0.15	−0.69	1.00
bs(Pod/bl prop.)1:Temperature	−0.75	−3.18	1.80
bs(Pod/bl prop.)2:Temperature	1.07	−0.70	2.66
bs(Pod/bl prop.)3:Temperature	−1.24	−2.11	−0.46
Time:Island	−0.87	−1.30	−0.42
bs(Pod/bl prop.)1:Island	−0.41	−1.44	0.39
bs(Pod/bl prop.)2:Island	0.75	0.09	1.41
bs(Pod/bl prop.)3:Island	−0.23	−0.63	0.22
Temperature:Island	0.17	−0.13	0.47
Time:Forest cover	−1.33	−2.91	0.33
Island:Forest cover	−0.87	−1.49	−0.26
Time:bs(Pod/bl prop.)1:Temperature	−2.25	−5.92	1.13
Time:bs(Pod/bl prop.)2:Temperature	0.24	−2.32	2.66
Time:bs(Pod/bl prop.)3:Temperature	−0.14	−1.33	1.06
Time:bs(Pod/bl prop.)1:Island	0.32	−0.93	1.82
Time:bs(Pod/bl prop.)2:Island	−1.39	−2.29	−0.47
Time:bs(Pod/bl prop.)3:Island	0.21	−0.42	0.78
Time:Temperature:Island	-0.11	−0.55	0.34
bs(Pod/bl prop.)1:Temperature:Island	-0.30	−1.70	1.01
bs(Pod/bl prop.)2:Temperature:Island	0.30	−0.80	1.35
bs(Pod/bl prop.)3:Temperature:Island	0.61	0.16	1.10
Time:Island:Forest cover	0.44	−0.46	1.36
Time:bs(Pod/bl prop.)1:Temperature:Island	1.55	−0.30	3.55
Time:bs(Pod/bl prop.)2:Temperature:Island	−1.28	−2.81	0.28
Time:bs(Pod/bl prop.)3:Temperature:Island	0.09	−0.63	0.77

Appendix S7. Parameter estimates and standard errors from a generalised linear mixed effect model (with poisson error and log link function) of the number of non-fern plant species per plot. The model had three interacting terms: forest type (podocarp and/or broadleaved, contrasted with beech), estimated mean annual temperature at the plot (from LENZ; Leathwick et al. 2003) and Island (North or South). Estimates are shown on the log scale of the link function.

Variable	Estimate	Standard error	z value	P
Intercept	2.504	0.233	10.761	< 0.001
Podocarp-broadleaved	1.080	0.317	3.403	0.001
Mean annual temperature	0.011	0.002	4.380	0.000
Island	0.273	0.127	2.146	0.032
Podocarp-broadleaved:				
Mean annual temperature	−0.012	0.003	−3.890	< 0.001
Podocarp-broadleaved:Island	−0.486	0.190	−2.556	0.011
Mean annual temperature:Island	−0.004	0.001	−2.984	0.003
Podocarp-broadleaved:				
Mean annual temperature:Island	0.007	0.002	3.499	< 0.001

Appendix S8. Fitted estimates of numbers of conifer and angiosperm (non-fern) species per plot in podocarp-broadleaved and beech forest classes (derived from Ecosat classes) plotted against mean annual temperature on the North and South Islands.
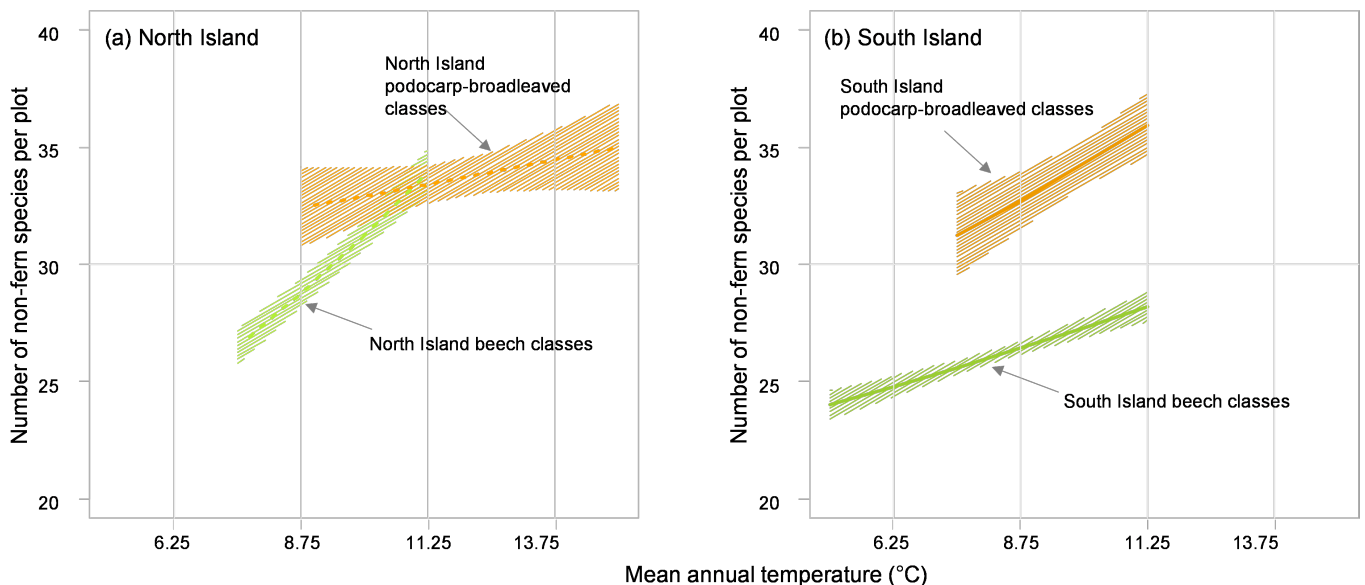
We tested our assumption about food resources by comparing the plot-level floristic diversity of podocarp-broadleaved and beech-dominated forests. We used data describing the number of species per 20 × 20 m plot (or species density) counted in the first measurement cycle of the Land Use and Carbon Analysis System program (LUCAS indigenous forests and shrublands; 1246 plots, over the period 2002–2007; see Holdaway et al. 2017 for details of methods). We analysed the number of conifer and angiosperm species per plot (non-fern species) to represent groups that provide flower and fruit as well as foliage food resources for kererū. We fitted a model of the number of non-fern species per plot (assuming a Poisson data distribution and a log link function) with three interacting terms: forest type (podocarp and/or broadleaved, or beech), mean annual temperature at the plot (from LENZ; Leathwick et al. 2003) and Island (North or South).

The LUCAS data show that numbers of non-fern plant species per plot (species density) were significantly higher in podocarp-broadleaved forest classes than in beech forest classes across New Zealand. This result is consistent with our expectation that there are more food resources for kererū in podocarp-broadleaved forests than in beech forest, assuming that food value is randomly distributed across those plant species. Total non-fern plant species density increased with temperature in both forest types across both islands. South Island beech forests had significantly fewer species per plot than North Island beech forests at similar temperatures, but podocarp-broadleaved forests on both islands supported similar numbers of species per plot.

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