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Supplementary material

A management experiment reveals the difficulty of altering seedling growth and palatable plant biomass by culling invasive deer

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S1. Our adaptive management process

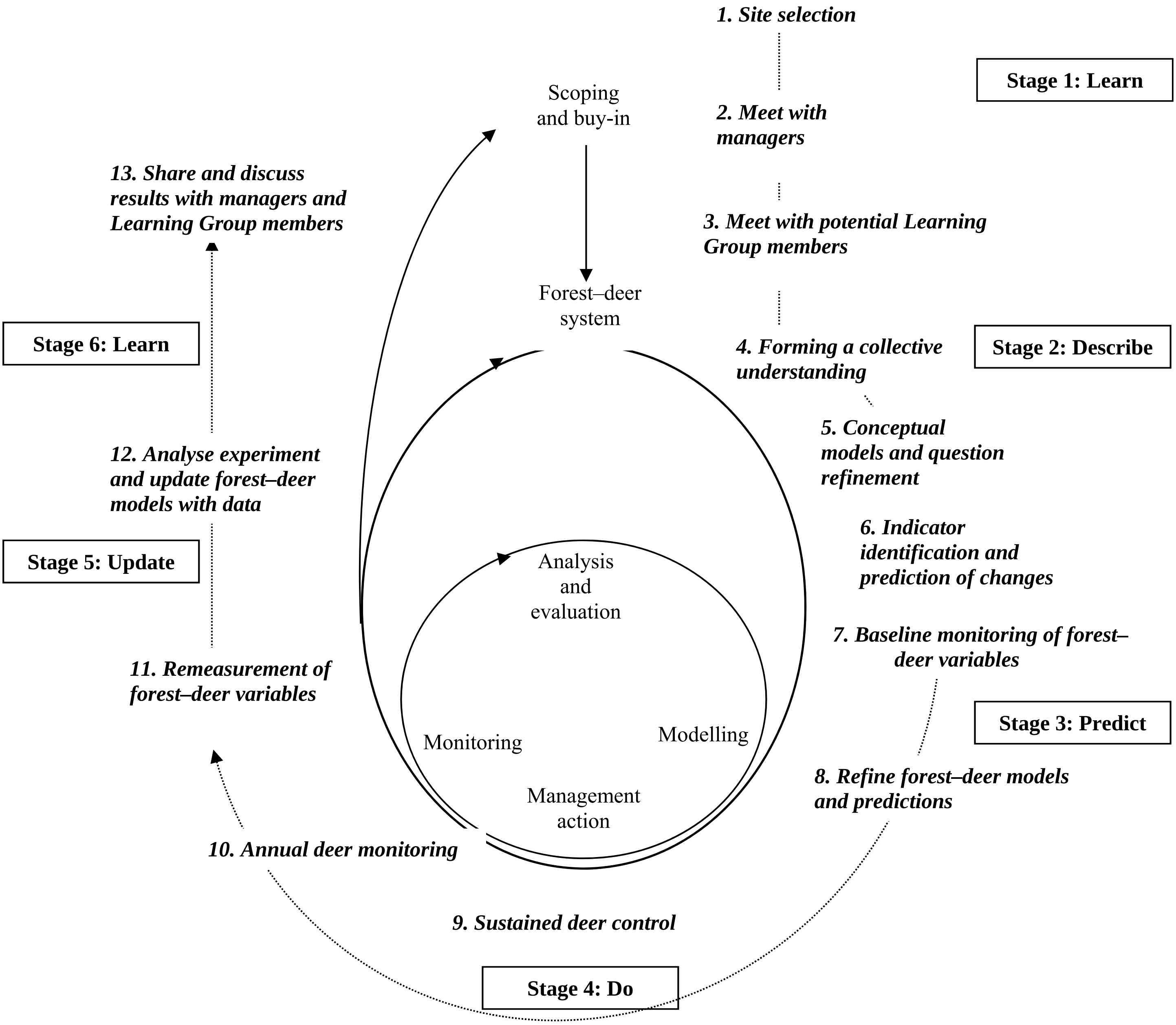

Fig. S1-1. Our adaptive management process. A detailed overview of the process is given in Jacobson *et al.* (2009). Steps 1−10 are described in Jacobson *et al.* (2009), Ramsey *et al.* (2012) and Forsyth *et al.* (2013). This paper describes steps 11 and 12. A subsequent publication will describe step 13.

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S2. Locations of the four forests studied in the North and South islands, New Zealand

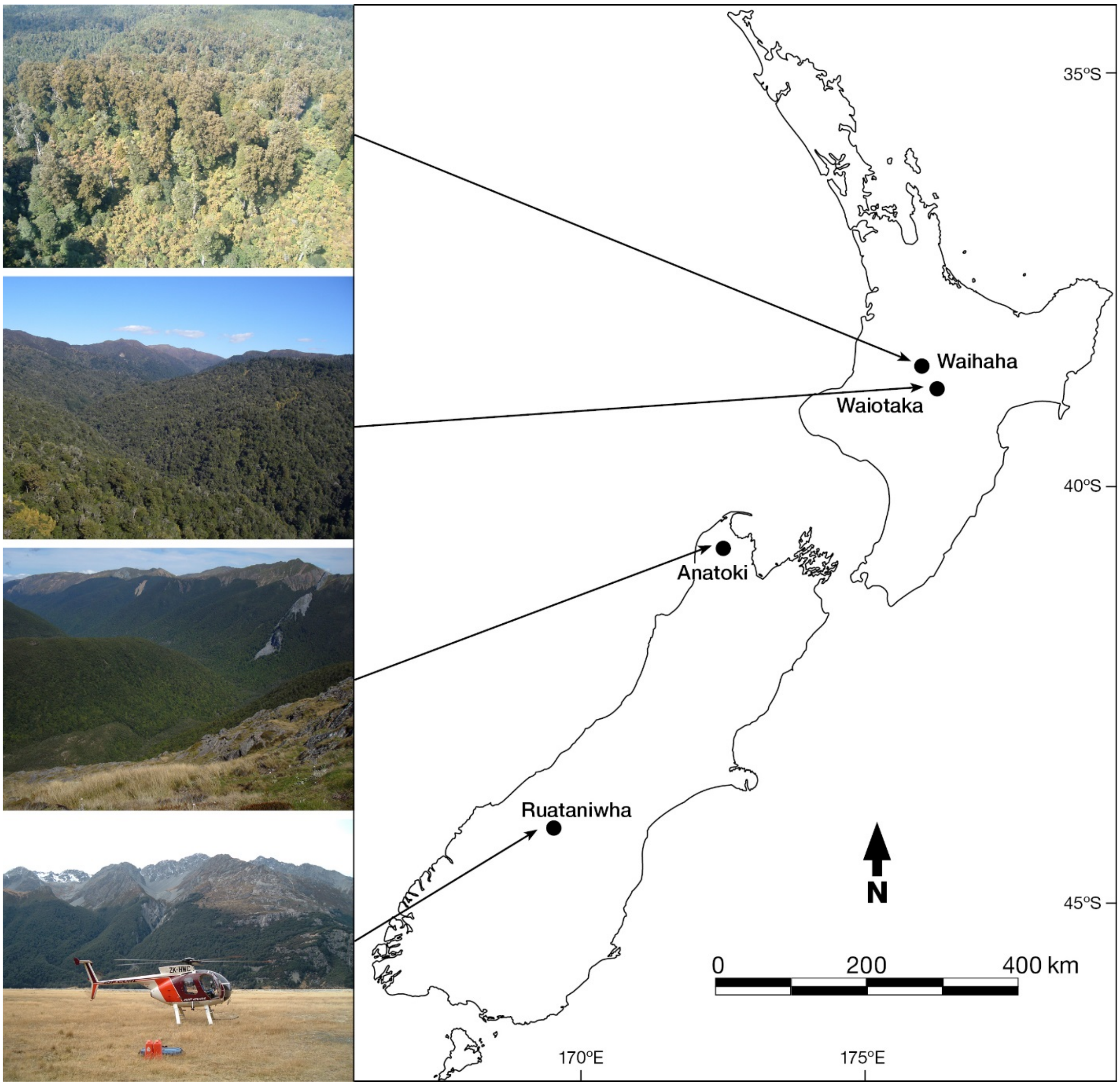

Fig. S2-1. The four forests studied in the North and South islands, New Zealand: Waihaha (subject to deer culling), Waiotaka (subject to deer culling), Anatoki (not subject to deer culling) and Ruataniwha (subject to deer culling).

S3. Physiognomic-based classification of the four forests

Plant composition data were collected in 10 m × 10 m plots at the start of Faecal Pellet Index transects established in each of the four forests (Richardson et al. 2010). These data were used to classify each forest following Wiser et al. (2011) and Wiser and DeCáceres (2013).

The four forests represent three of the five extensive physiognomic-based groups in New Zealand's indigenous forests (Wiser et al. 2011): Nothofagus forests (Ruataniwha); Nothofagus–broad-leaved forests (Waiotaka and Anatoki); and, mostly broad-leaved–podocarp forests (Waihaha). At Ruataniwha, 45.5% of 101 plots were *Nothofagus solandri* (*Peraxilla tetrapetala*) / (*Coprosma pseudocuneata*) subalpine forest, 44.5% were *Nothofagus solandri – Nothofagus menziesii* / *Coprosma pseudocuneata – Hymenophyllum multifidum* forest, and 9.9% were in four other forest types. At Waiotaka, 38% of 87 plots were *Pseudowintera colorata – Griselinia littoralis – Nothofagus fusca* (*Nothofagus menziesii*) / *Microlaena avenacea* forest and successional shrubland, 24% were *Nothofagus menziesii – Weinmannia racemosa – Nothofagus fusca* / *Blechnum discolor* forest, 11% were *Weinmannia racemosa – Cyathea smithii – Prumnopitys ferruginea* / *Blechnum discolor* forest, and 7% were *Weinmannia racemosa – Griselinia littoralis – Pseudowintera colorata* / *Blechnum discolor* forest, with 26% in eight other forest types. At Anatoki, 32% of 100 plots were *Nothofagus menziesii – Weinmannia racemosa –Nothofagus fusca* / *Blechnum discolor* forest, 20% were *Nothofagus menziesii – Griselinia littoralis – Myrsine divaricata* / *Coprosma foetidissima* forest, 9% were *Nothofagus solandri – Nothofagus menziesii* / *Coprosma pseudocuneata – Hymenophyllum multifidum* forest, 9% were *Weinmannia racemosa – Cyathea smithii – Prumnopitys ferruginea* / *Blechnum discolor* forest, and 30% were in six other forest types. At Waihaha, 40.9% of 132 plots were *Pseudowintera colorata – Fuchsia excorticata – Griselinia littoralis* / *Polystichum vestitum* forest, 24.2% were *Weinmannia racemosa – Cyathea smithii – Prumnopitys ferruginea* / *Blechnum discolor* forest, 13.6% were *Pseudowintera colorata – Griselinia littoralis – Nothofagus fusca* (*Nothofagus menziesii*) / *Microlaena avenacea* forest and successional shrubland, 7.6% were *Melicytus ramiflorus – Cyathea smithii – Dicksonia squarrosa – Carpodetus serratus* (*Beilschmiedia tawa*) forest, and 13.6% were in five other forest types.

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S4. Prediction of percentage photosynthetic active radiation on vegetation plots using an Artificial Neural Network model

The percentage photosynthetic active radiation (%PAR) reaching vegetation plots was estimated using hemispherical photography. However, this method was unsuccessful on 212 of the 481 vegetation plots. We, therefore, estimated %PAR using measured environmental attributes. Our general approach was to model observed %PAR values with environmental variables and then predict %PAR values for the remaining plots. The four potential predictors were: elevation (m), canopy height (m), weighted mean leaf size (mm^2) and total cover score of species >2 m (%). The training data consisted of 212 vegetation plots.

We used an Artificial Neural Network (ANN) model because it can describe highly non-linear data (Lek *et al*. 1996). We used the R package 'nnet' 7.3-8 (Ripley 2014), which implements feed-forward ANN with one hidden layer, to implement our model. Two parameters must be set by the user. The parameter 'size' determines the number of units (neurons) in the ANN, and the parameter 'decay' determines the decay of the weights as the ANN is updated. The values we used in our model (size = 23 and decay = 0.001) were chosen using a leave-one-out cross-validation procedure. We removed the first observation from the training data and used the remaining 211 cases to train the ANN. The trained model was then used to predict the %PAR value for the one observation left out. The discrepancy between the predicted and observed %PAR value was calculated as the squared error $(Obs - Pred)^2$. This was then repeated for the next observation and so on until each observation was left out in turn. The average of the squared error terms was used as the estimate of predictive accuracy for a particular set of tuning parameters. We repeated the above cross-validation procedure and conducted a grid search over combinations of size and decay, performing cross-validation on each combination of parameters. The combination with the lowest mean squared error was selected as the best ANN model (Fig. S4-1) and used to predict PAR values for each vegetation plot in the dataset having values for each of the four predictors.

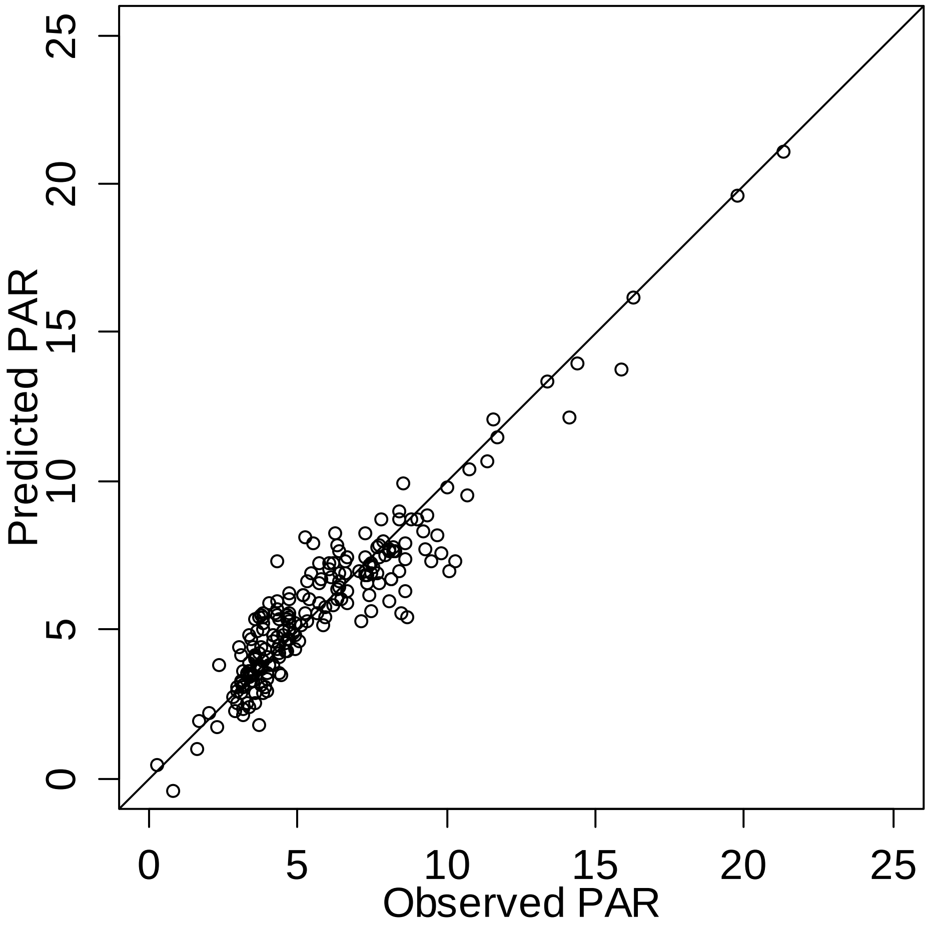

Fig. S4-1. Predicted and observed percentage photosynthetic active radiation (%PAR) for the training data (*n* = 212 vegetation plots) from the best Artificial Neural Network model.

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S5. Classification of plant species as palatable or unpalatable to deer

Palatability was defined from rumen studies, exclosure and controlled grazing studies, and (where no other information for a plant species was available) using documented accounts of vegetation change following the establishment of deer populations in various regions of New Zealand. We defined 'palatable' species as those that are eaten proportionally more than expected from their availability (Forsyth *et al.* 2002). Palatable species often respond positively to the removal of ungulates (e.g. through fencing or controlled grazing), and eyewitness accounts often identify that these species are the first to be browsed when deer establish in a forest (e.g. Mark and Baylis 1975). Other plant species are either eaten in proportion to their availability or less than expected from their availabililty (Forsyth *et al.* 2002): we grouped these as 'unpalatable' in our classification. If a plant species was not classified in any published study, then we assumed that if all congenerics were palatable then that species would also be palatable. If palatability varied within a genus, or where no information was available for the species or genus, then we conservatively assumed the species was unpalatable. There was insufficient information to classify some species/taxa, but these constituted only 7.8% of the total of 9748 point height intercepts; those species/taxa are listed in Appendix 1 of Richardson *et al.* (2010).

Table S5-1. Species/taxa classified as 'palatable' to deer

Species/taxa are listed in descending order of number of point height intercepts in the data

Species/taxa	Source	Point height intercepts
Polystichum vestitum	Mark and Baylis 1975	285
Griselinia littoralis	Forsyth *et al.* 2002	151
Weinmannia racemosa	Forsyth *et al.* 2002	131
Pseudopanax crassifolius	Forsyth *et al.* 2002	68
Coprosma tenuifolia	Forsyth *et al.* 2002	48
Pseudopanax colensoi	Forsyth *et al.* 2002	22
Asplenium bulbiferum	Mark and Baylis 1975	17
Aristotelia serrata	Forsyth *et al.* 2002	11
Asplenium flaccidum	Forsyth *et al.* 2002	10
Ripogonum scandens	Forsyth *et al.* 2002	9
Melicytus ramiflorus	Forsyth *et al.* 2002	8
Coprosma grandifolia	Forsyth *et al.* 2002	7
Coprosma lucida	Forsyth *et al.* 2002	6
Myrsine australis	Forsyth *et al.* 2002	5
Schefflera digitata	Forsyth *et al.* 2002	5
Anisotome haastii	Rose and Platt 1987	3
Geniostoma ligustrifolium	Forsyth *et al.* 2002	2
Raukaua edgerleyi	Forsyth *et al.* 2002	2
Pseudopanax arboreus	Forsyth *et al.* 2002	1
Hoheria lyallii	Stewart *et al.* 1987: *Hoheria glabrata*	1
Chionochloa pallens	Rose and Platt 1987	1

Table S5-2. Species/taxa classified as ‘unpalatable’ to deer

Species/taxa are listed in descending order of number of point height intercepts in the data

Species/taxa	Source(s)	Point height intercepts
Nothofagus solandri var. *cliffortioides*	Forsyth *et al.* 2002	840
Microlaena avenacea	Wardle 1991	603
Blechnum discolor	Forsyth *et al.* 2002	557
Pseudowintera colorata	Forsyth *et al.* 2002	520
Uncinia uncinata	Wardle 1967	509
Podocarpus nivalis	Wardle 1974	455
Blechnum fluviatile	Forsyth *et al.* 2002	368
Leptopteris hymenophylloides	Forsyth *et al.* 2002	308
Metrosideros diffusa	Forsyth *et al.* 2002	230
Hymenophyllum revolutum	Forsyth *et al.* 2002	202
Hymenophyllum multifidum	Forsyth *et al.* 2002	194
Neomyrtus pedunculata	Forsyth *et al.* 2002	192
Uncinia filiformis	Wardle 1967	157
Hymenophyllum spp.	Forsyth *et al.* 2002	152
Coprosma tayloriae	Husheer *et al.* 2006	151
Blechnum procerum	Forsyth *et al.* 2002	142
Trichomanes reniforme	Forsyth *et al.* 2002	138
Nothofagus menziesii	Forsyth *et al.* 2002	132
Leptopteris superba	Wardle 1974	116
Uncinia spp.	Wardle 1967	109
Coprosma foetidissima	Forsyth *et al.* 2002	105
Blechnum penna-marina	Forsyth *et al.* 2002	97

Coprosma pseudocuneata	Wardle and Hayward 1970; Wardle 1974; Stewart *et al.* 1987	96
Hymenophyllum demissum	Forsyth *et al.* 2002	81
Dracophyllum recurvum	Stewart et al. 1987	65
Phyllocladus alpinus	Wardle and Hayward 1970; Wardle *et al.* 1973; Stewart et al. 1987	62
Dicksonia lanata	Cunningham 1979; James and Wallis 1969; Wardle 1991	61
Nothofagus fusca	Forsyth *et al.* 2002	52
Uncinia rupestris	Wardle 1967	51
Podocarpus hallii	Forsyth *et al.* 2002	49
Cyathea smithii	Forsyth *et al.* 2002	45
Nestegis cunninghamii	Forsyth *et al.* 2002	39
Raukaua anomalus	Stewart *et al.* 1987	39
Blechnum chambersii	Forsyth *et al.* 2002	38
Grammitis billardierei	Forsyth *et al.* 2002	35
Histiopteris incisa	Forsyth *et al.* 2002	34
Gaultheria antipoda	Forsyth *et al.* 2002	33
Rubus cissoides	Forsyth *et al.* 2002	33
Prumnopitys ferruginea	Forsyth *et al.* 2002	31
Dicksonia squarrosa	Forsyth et al. 2002	30
Myrsine salicina	Forsyth *et al.* 2002	29
Carpodetus serratus	Forsyth *et al.* 2002	28
Cortaderia fulvida	Rogers and Leathwick 1997: *Cortaderia toetoe*	28
Blechnum colensoi	Forsyth *et al.* 2002	27
Lepidothamnus intermedius	Stewart *et al.* 1987	26

Lepidothamnus laxifolius	Forsyth *et al.* 2002	26
Elaeocarpus hookerianus	Forsyth *et al.* 2002	25
Hymenophyllum sanguinolentum	Forsyth *et al.* 2002	23
Nestegis lanceolata	Forsyth *et al.* 2002	23
Chionochloa spp.	Wardle 1991	22
Dacrydium cupressinum	Forsyth *et al.* 2002	21
Gahnia procera	Wardle 1974	21
Pseudopanax linearis	Wardle 1974, Stewart *et al.* 1987	21
Archeria traversii	Wardle and Hayward 1970, Stewart *et al.* 1987	20
Hymenophyllum dilatatum	Forsyth *et al.* 2002	20
Hypolepis distans	Forsyth *et al.* 2002	20
Coprosma rhamnoides	Forsyth *et al.* 2002	19
Dracophyllum traversii	Wardle and Hayward 1970	18
Muehlenbeckia australis	Forsyth *et al.* 2002	18
Cyathea colensoi	Wardle 1974	17
Coprosma colensoi	Wardle 1974; Stewart *et al.* 1987	16
Phormium cookianum	Wardle 1974	16
Dracophyllum longifolium	Forsyth *et al.* 2002	15
Hypolepis millefolium	Forsyth *et al.* 2002	15
Celmisia spectabilis	Wardle 1971	13
Hebe stricta	Forsyth *et al.* 2002	13
Nertera dichondrifolia	Wardle 1991	13
Pentachondra pumila	Wardle 1991	13
Raukaua simplex	Forsyth *et al.* 2002	13
Astelia fragrans	Wardle 1984	12
Chionochloa rigida	Wardle 1991	11

Dracophyllum menziesii	Stewart *et al.* 1987	11
Gaultheria depressa	Stewart *et al.* 1987: *Gaultheria antipoda* and *G. ruprestris*	11
Phyllocladus trichomanoides	Forsyth *et al.* 2002	11
Prumnopitys taxifolia	Forsyth *et al.* 2002	11
Cyathodes juniperina	Forsyth *et al.* 2002	10
Androstoma empetrifolia	Wardle 1991	8
Grammitis spp.	Forsyth *et al.* 2002	8
Coprosma propinqua	Forsyth *et al.* 2002	7
Metrosideros umbellata	Forsyth *et al.* 2002	6
Astelia nervosa	James and Wallis 1969; Wardle 1971, 1974	6
Cortaderia toetoe	Rogers and Leathwick 1997	6
Lagenifera strangulata	Wardle 1991	6
Parsonsia spp.	Forsyth *et al.* 2002	6
Podocarpus totara	Wardle 1971	6
Rytidosperma gracile	Wardle 1991	6
Coprosma ciliata	Wardle and Hayward 1970; Wardle 1974, Stewart *et al.* 1987	5
Cyathea dealbata	Forsyth *et al.* 2002	5
Gahnia spp.	Wardle 1974: *Gahnia procera*	5
Hebe odora	Stewart *et al.* 1987	5
Leptospermum scoparium	Forsyth *et al.* 2002	5
Nothofagus truncata	Wardle 1974	5
Astelia trinervia	Wardle 1984	4
Clematis paniculata	Forsyth *et al.* 2002	4

Dracophyllum spp.	Wardle 1991	4
Astelia solandri	Wardle 1984	3
Beilschmiedia tawa	Forsyth *et al.* 2002	3
Hedycarya arborea	Forsyth *et al.* 2002	3
Hymenophyllum rufescens	Forsyth *et al.* 2002	3
Hymenophyllum villosum	Forsyth *et al.* 2002	3
Olearia colensoi	Wardle 1974, Stewart *et al.* 1987	3
Pennantia corymbosa	Forsyth *et al.* 2002	3
Tmesipteris spp.	Forsyth *et al.* 2002	3
Asplenium hookerianum	Forsyth *et al.* 2002	2
Asplenium polyodon	Forsyth *et al.* 2002	2
Coprosma cheesemanii	Rose and Platt 1987	2
Dracophyllum uniflorum	Wardle 1971; 1974	2
Gaultheria species	Stewart *et al.* 1987: *Gaultheria antipoda* and *G. ruprestris*	2
Hymenophyllum bivalve	Forsyth *et al.* 2002	2
Hymenophyllum flabellatum	Forsyth *et al.* 2002	2
Hymenophyllum scabrum	Forsyth *et al.* 2002	2
Nertera depressa	Wardle 1991	2
Nothofagus solandri var. *cliffortioides* × *fusca*	Forsyth *et al.* 2002	2
Rytidosperma spp.	Wardle 1991	2
Uncinia banksii	Wardle 1967	2
Uncinia nervosa	Wardle 1967	2
Aristotelia fruticosa	Stewart *et al.* 1987	1
Elaeocarpus dentatus	Forsyth *et al.* 2002	1

Gaultheria crassa	Stewart *et al.* 1987: *Gaultheria antipoda* and *G. ruprestris*	1
Halocarpus bidwillii	Wardle and Hayward 1970; Stewart *et al.* 1987: *Halocarpus biforme*	1
Hymenophyllum lyallii	Forsyth *et al.* 2002	1
Hymenophyllum rarum	Forsyth *et al.* 2002	1
Leptopteris spp.	Forsyth *et al.* 2002	1
Melicope simplex	Forsyth *et al.* 2002	1
Nothofagus solandri	Forsyth *et al.* 2005	1
Olearia lacunosa	Wardle 1974	1
Ozothamnus leptophyllus	Wardle 1971	1
Phyllocladus toatoa	James and Wallis 1969; Wardle 1991	1
Pteridium esculentum	Forsyth *et al.* 2002	1
Rhabdothamnus solandri	Forsyth *et al.* 2002	1
Rubus spp.	Forsyth *et al.* 2002	1
Tmesipteris elongata	Forsyth *et al.* 2002	1

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S6. Regression equation parameters describing the relationships between total dry mass of unseparated material and the dry mass of foliar material for understorey plant species

Allometric relationships were estimated for common species and for at least one species in each physiognomic growth form. The relationships were estimated by fitting linear regression models to the $\log_{10}$-transformed data using the *lm* function in R (R Development Core Team 2013). The allometric relationships were then applied to species with a similar shape and form (e.g. small-leaved, prostrate shrubs; large-leaved lianes).

Table S6-1. Regression equation parameters describing the relationships between total dry mass of unseparated material and the dry mass of foliar material for understorey plant species

Species are given as six letter codes corresponding to the first three letters from the genus and species names; a full list of codes and names is available at https://nvs.landcareresearch.co.nz/Resources/NVSNames

Species measured for allometry	Intercept	Slope	*N*	r^2	Species for which the allometry was applied
ARCTRA	–0.75	0.84	20	0.60	ANDEMP, ARCTRA, DACCUP, DACDAC, EPAALP, FORBID, FORSED, HALBID, HALBIF, KUNERI, LEPJUN, LEPLAX, LEPSCO, PENPUM
ARISER	–3.07	2.33	2	1.00	ARISER
BEITAW	–0.64	0.78	18	0.83	ALSPUS, BEITAW
BRABID	–0.32	0.88	18	0.81	BRAADA, BRABID, BRACHY, BRAREP, BRAROT, PSETRA
CARSER	–1.00	0.42	17	0.47	CARSER
COPCOL	–0.90	0.81	18	0.87	COPCOL, COPCUN, COPPRO,
COPDEP	–0.95	0.94	25	0.98	COPDEP, UNKNOW

COPFOE	–0.86	0.70	19	0.89	COPFOE, COPPXR, HELLAN
COPGRA	–0.81	0.87	8	0.97	COPGRA
COPLUC	–0.78	0.82	3	1.00	COPLUC
COPPSC	–1.30	0.90	18	0.90	COPCIL, COPPSE, COPRHA, PITRIG
COPPSE	–0.70	0.78	70	0.88	COPPSE
COPTAY	–1.07	0.71	32	0.56	COPDUM, COPMIC, COPROS, COPRUB, COPTAY, COPTEF
DRALON	–2.46	2.08	3	0.65	DRALON
DRAMEN	1.27	0.34	2	1.00	DRAPUB, DRASUB, DRAUNI
DRAREC	–0.63	0.90	18	0.97	DRAREC
DRATRA	–0.45	0.93	18	0.78	CORBAN, CORIND, DRATRA
ELADEN	–1.10	0.45	19	0.61	ELADEN
ELAHOO	–0.98	0.67	20	0.96	ELAHOO
GAUANT	–0.61	0.61	10	0.53	GAUANT
GAUCRA	–1.12	1.10	8	0.63	GAUCRA
GAUDEP	–0.61	0.91	2	1.00	ANABEL, GAUDEP, GAUDVN
GRILIT	–0.86	0.93	32	0.95	GRILIT
HEBE	–0.81	0.57	2	1.00	HEBE
HEBODO	–0.56	0.81	16	0.76	HEBALB, HEBCAN, HEBLEI, HEBODO
HEBSTR	–1.77	1.16	7	0.67	HEBPAR, HEBPVA, HEBSAL, HEBSTR
HEBSUB	–0.46	0.48	3	0.23	HEBSUB
HOHLYA	–1.11	0.78	4	0.98	HOHLYA, URTFER
KNIEXC	–0.62	1.04	8	0.95	KNIEXC
LEUFAS	–0.75	0.86	19	0.93	LEUFAS
MELLAN	–0.69	0.24	2	1.00	HEDARB, MELLAN
MELRAM	–1.23	0.51	2	1.00	GENLIG, MELRAM
MELSIM	–1.15	0.37	19	0.32	MELSIM

METDIF	–1.01	1.03	17	0.93	METDIF, METPER
METFUL	–1.44	1.18	23	0.47	METFUL
METUMB	–0.66	0.90	18	0.95	METROB, METUMB
MUEAUS	–1.33	0.58	17	0.84	MUEAUS, MUEAXI, MUEHLE
MYRAUS	–1.04	0.49	3	0.50	MYRAUS
MYRDIV	–1.04	0.79	47	0.85	MYRDIV
MYRNUM	–0.63	0.81	26	0.94	MYRNUM
MYRSAL	–0.82	0.97	19	0.93	MYRSAL
NEOPED	–1.01	0.79	20	0.82	NEOPED
NESCUN	–0.82	0.87	20	0.90	NESCUN, NESLAN, NESTEG
NOTCLI	–0.80	0.89	26	0.88	NOTCLI, NOTSOL
NOTFUS	–0.73	0.81	19	0.95	NOTFUS, PITCOL
NOTMEN	–0.66	0.92	32	0.98	NOTMEN
OLENUM	–0.59	0.97	11	0.99	HEBTET, OLEARB, OLEAVI, OLECOL, OLEFUR, OLEILI
PHYALP	–0.66	0.99	24	0.99	PHYALP, PHYTOA, PHYTRI
PODHAL	–0.69	0.89	18	0.94	PODHAL, PODHXN, PODTOT
PODNIV	–0.64	0.97	18	0.99	PODNIV
PRUFER	–0.86	0.82	18	0.94	PRUFER, PRUTAX
PSECOL	–0.88	1.03	38	0.94	PSEAXI, PSECOL
PSECRA	–0.78	0.97	13	0.93	PSECRA
PSELIN	–0.60	0.92	19	0.95	OLELAC, PSELIN
QUISER	–0.65	0.87	19	0.95	QUISER
RAUANO	–1.08	0.77	19	0.94	ARIFRU, PENCOR, RAUANO
RAUSIM	–0.74	0.66	15	0.59	RAUSIM
RIPSCA	–0.96	0.84	6	0.88	CLEPAN, PARCAP, PARHET, PARSON, RIPSCA, RUBCIS, RUBSCH
WEIRAC	–0.71	0.70	7	0.86	WEIRAC

Reference

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S7. Trends in deer/feral goat abundances at Anatoki

Statistical analyses

The Faecal Pellet Index (FPI) data were characterised by a high frequency of zero counts and strong overdispersion. Hence, zero-inflated negative binomial (ZINB) regression (Ntzoufras 2009) was used to model the counts of pellets (Y_{ij}) on different transects (indexed by i) in each year, j (Forsyth *et al*. 2013). The ZINB model is a mixture model that combines a point mass on zero with a count process. Hence, the zeros were modelled as coming from two processes: a binomial process (Bernoulli random variable) used to model the 'excess' zero observations and a count process (NB model). The advantage of the mixture-model approach is the ability to separate out the sources of the zero inflation and gain insight into whether they are being influenced by the covariates in different ways. Inferences are made about the expected abundance (i.e. the count process including the probability of structural 'true' zeros) multiplied by the probability of not getting a 'false' zero (i.e. the observation and/or detection process), given environmental covariates.

To account for the same transects being sampled annually, we included 'transect' as a random effect in our model. 'Site' and 'treatment' were fitted as fixed effects in the model. We were interested in estimating the trend in FPI (i.e. deer-population growth rate) at each of the treatment and non-treatment areas at the three sites at which deer culling was conducted, and at the North and South areas at the Anatoki site (where culling was not conducted). These trends were estimated in the presence of the random effects by fitting hierarchical ZINB models to the data by using Markov Chain Monte Carlo (MCMC) methods in OpenBugs ver. 3.2.1 (Thomas *et al*. 2006). The following model definition was used:

$$Y_{ij} = NB(u_{ij}, r_z),$$

$$u_{ij} = \frac{r_z}{r_z + \lambda_{ij}(1 - U_{ij})},$$

$$U_{ij} = Bern(p_{ij})$$

$$\log(\lambda_{ij}) = \alpha_z + \beta_z \times (j - 1) + u_i,$$

$$\log\left(\frac{p_{ij}}{1 - p_{ij}}\right) = \eta_z \text{, and}$$

$$u_i \sim N(0, \sigma^2),$$

where Y_{ij} is the FPI on transect *i* in Year *j*, and μ, *r* and λ are the parameters of the negative binomial distribution. Under the parameterisation of the ZINB given above, the expected value of the counts is equal to

$$E(Y_{ij}) = e^{\lambda_{ij}}(1 - p_{ij}).$$

The α_z and β_z are the fixed-effect intercept (Year 1) and the FPI growth rate predictors varying by covariate *z* (i.e. 'site' and 'treatment'). The parameter r_z of the NB distribution was also indexed by 'site' and 'treatment'. Similarly, the parameter η_z represents the logit probability of obtaining a 'false zero' observation, again indexed by site and treatment, and u_i is the random effect of transect *i*, having a mean of 0 and variance of σ^2. The ZINB model partitions the observed zero counts into those resulting from detection error (false zeros) with probability *P* (i.e. deer pellets were present but not detected), with the remainder (1 – *P*) being the 'true' or structural zeros resulting from the count process (i.e. deer pellets were not present). We considered that detection error *P* would most likely vary at each forest and area because of differences in site characteristics (i.e. ground-layer vegetative cover) but was unlikely to vary over the course of the study. Hence, we did not consider any temporal variation in *P*.

Vague normal priors $N(0, 100\,000)$ were placed on Parameters α, β and η, a vague gamma prior $Ga(0.001,0.001)$ was placed on the NB parameter r, and a vague uniform prior $U(0,100)$ was placed on the random-effect parameter σ. Three MCMC chains were run with diffuse initial values and checked for convergence using the Brooks–Gelman–Rubin convergence statistic (Brooks and Gelman 1998), with convergence achieved after 30 000 'burn-in' iterations. Thereafter, sampling continued for 10 000 samples for each chain, giving 30 000 samples for posterior summaries.

The goodness of fit of our model to the data was assessed by comparing the discrepancy of the posterior predictive distribution with the observed data by using a chi-squared statistic. The posterior predictive distribution consisted of 1000 replicated datasets drawn from the posterior distribution conditioned on the model parameters. The proportion of times the test statistic for the replicated data was less than or equal to the value for the observed data is the Bayesian *P*-value, with values close to 0 or 1 indicating lack of fit (Gelman *et al*. 1996).

Results

Model adequacy

Trace plots of chains for each parameter (not shown) indicated that the chains were well mixed and all parameters had *R*-hat values close to 1.0, indicating convergence of the chains and a reliable sample for posterior inference. The Bayesian *P*-value of 0.61 suggested that the model provided a reasonable approximation to the observed data, which was confirmed by examining plots of the Pearson residuals and the chi-squared discrepancy (Fig. S7-1).

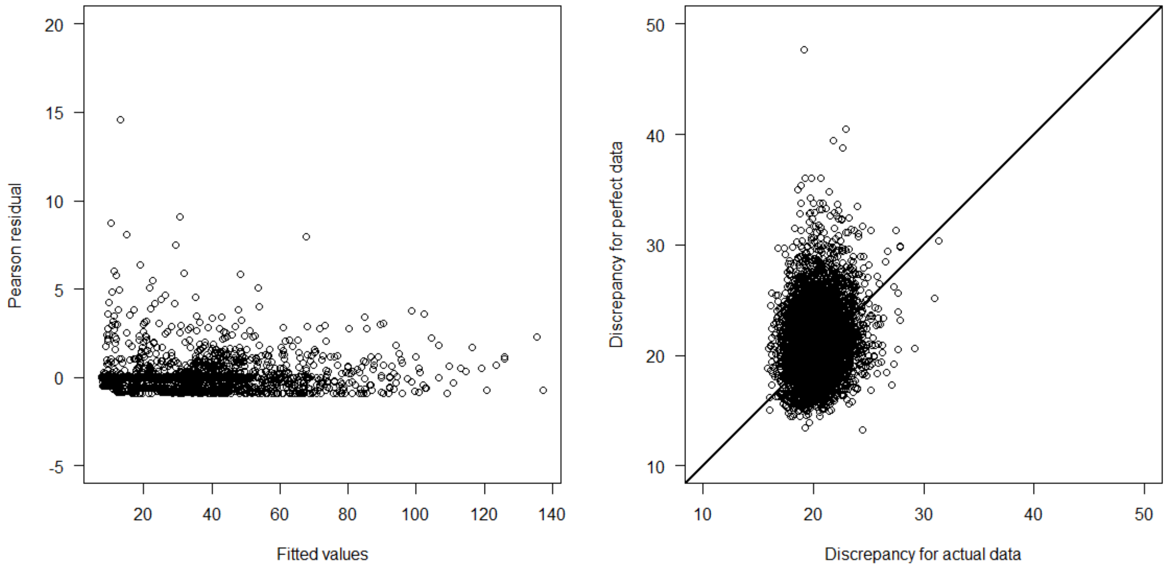

Fig. S7-1. Pearson residuals (left) and chi-squared discrepancy plot (right) from the posterior predictive distribution for the Bayesian zero-inflated negative binomial (ZINB) regression. The solid line indicates the 1:1 relationship. Chi-squared values have been divided by 10^4 for clarity.

Trends in deer/feral goat abundances at Anatoki

At Anatoki, deer/feral goat FPI ($\log_e$) growth rates were similar in the North (mean = 0.028; 95% CI = −0.202, 0.263) and South (0.058; −0.107, 0.309) areas (Table S7-1). The estimated parameters of the modelled observation process (i.e. the probability of obtaining false zero observations) showed high variation among sites (Table S7-2). The probability of detecting one or more pellets on a transect in the North and South areas at Anatoki were 0.65 and 0.30, respectively (Table S7-2).

Table S7-1. Parameter estimates for the annual Faecal Pellet Index (FPI) trend in each area within the four forests

α is the $\log_e$ FPI in year 1 and β is the $\log_e$ annual growth rate

Study site and area	Parameter estimates					
	α	2.5%	97.5%	*β*	2.5%	97.5%
Waihaha						
Non-treatment area	4.71	4.48	4.95	−0.162	−0.232	−0.088
Treatment area	3.97	3.73	4.22	0.033	−0.024	0.088
Waiotaka						
Non-treatment area	2.47	2.09	2.86	0.319	0.226	0.416
Treatment area	3.49	3.14	3.84	0.075	0.001	0.159
Ruataniwha						
Non-treatment area	3.87	3.32	4.48	0.051	−0.077	0.183
Treatment area	3.51	2.99	4.05	0.034	−0.082	0.137
Anatoki						
North area	3.08	1.87	4.24	0.028	−0.202	0.263
South area	2.92	1.38	3.88	0.058	−0.107	0.309

Table S7-2. Parameter estimates for the observation process in each area within the four forests

η is the probability of a false-zero Faecal Pellet Index on a transect (on the logit scale). The complement of η is equivalent to the probability of detecting pellets on transects given that deer pellets are present (1−*P*)

Study site and area	Parameter estimates			
	η	2.5%	97.5%	1−*P*
Waihaha				
Non-treatment area	−1.39	−1.69	−1.11	0.80
Treatment area	−0.64	−0.86	−0.41	0.65
Waiotaka				
Non-treatment area	−1.38	−1.82	−0.99	0.80
Treatment area	−1.08	−1.46	−0.74	0.75
Ruitaniwha				
Non-treatment area	0.69	0.42	0.96	0.34
Treatment area	1.09	0.80	1.39	0.26
Anatoki				
North area	−0.63	−6.32	0.34	0.65
South area	0.83	0.03	1.38	0.30

References

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Gelman, A. B., Meng, X. L., and Stern, H. (1996). Posterior predictive assessment of model fitness via realized discrepancies. *Statistica Sinica* **6**, 733–807.

Ntzoufras, I. (2009). 'Bayesian Modeling Using WinBUGS.' (Wiley: New York.)

Thomas, A., O'Hara, R., Ligges, U., and Sturtz, S. (2006). Making BUGS open. *R News* **6**, 12–17.

S8. JAGS code used to implement our SHRGR, FBP and FBU models

JAGS code for the Bayesian hierarchical models fitted to canopy tree seedling height relative growth rates (SHRGRs) and foliar biomass of palatable species (FBP) and unpalatable species (FBU) in the three forests in which deer control was conducted.

```
model  {

    for (i in 1:N) {

    sgr[i] ~ dnorm(mu[i],tau.eps)
    mu[i] <-beta[1] + beta[2]*light[i]
                    + beta[3]*topo[i]
                    + beta[4]*basal[i]
                    + beta[5]*treat[i]
                    + a1[block[i]] + a2[block[i],plot[i]]
    }


    for(j in 1:Nblock) {
      a1[j] ~ dnorm(0, tau.gamma)
        for(k in 1:Nplot[j]) {
          a2[j,k] ~ dnorm(0, tau.delta)
        }
      }


    tau.eps<- 1/(sig.eps*sig.eps)
    sig.eps ~ dunif(0,100)
```

```
    tau.gamma<- 1/(sig.gamma*sig.gamma)
    sig.gamma ~ dunif(0,100)

    tau.delta<- 1/(sig.delta*sig.delta)
    sig.delta ~ dunif(0,100)

    for(j in 1:5) {beta[j] ~ dnorm(0, 0.001)}

    }
```

JAGS code for the Bayesian structural equation models fitted to data collected in the four forests.

```
model  {

    for (i in 1:N) {

    sgr[i] ~ dnorm(sgr.mu[i],tau.sgr)
    fbp[i] ~ dnorm(fbp.mu[i],tau.fbp)
    fbu[i] ~ dnorm(fbu.mu[i],tau.fbu)

    sgr.mu[i] <- beta[1]*light[i] + beta[2]*topo[i] +
beta[3]*basal[i] + beta[4]*deer[i] + alpha[1]*fbp[i] +
alpha[2]*fbu[i] + a1[block[i]] + a2[block[i],plot[i]]

    fbp.mu[i] <- beta[5]*light[i] + beta[6]*topo[i] +
beta[7]*basal[i] + beta[8]*deer[i] + a3[block[i]] +
a4[block[i],plot[i]]
```

```
    fbu.mu[i] <- beta[9]*light[i] + beta[10]*topo[i] +
beta[11]*basal[i] + a5[block[i]] + a6[block[i],plot[i]]

    }

    for(j in 1:Nblock) {
    a1[j] ~ dnorm(0, tau.sgr.block)
    a3[j] ~ dnorm(0, tau.fbp.block)
    a5[j] ~ dnorm(0, tau.fbu.block)
    for(k in 1:Nplot[j]) {
    a2[j,k] ~ dnorm(0, tau.sgr.plot)
    a4[j,k] ~ dnorm(0, tau.fbp.plot)
    a6[j,k] ~ dnorm(0, tau.fbu.plot)
    }
    }
    # Model selection
    for(j in 1:2) {
      gam[j] ~ dbern(0.5)
      betaG[j] ~ dnorm(0, tau.beta)
      alpha[j]<- gam[j] * betaG[j]
    }

    for(j in 3:p) {
    gam[j] ~ dbern(0.5)
    betaG[j] ~ dnorm(0, tau.beta)
    beta[j-2]<- gam[j] * betaG[j]
```

```
}

tau.sgr<- 1/(sig.sgr*sig.sgr)
sig.sgr ~ dunif(0,100)
tau.fbp<- 1/(sig.fbp*sig.fbp)
sig.fbp ~ dunif(0,100)
tau.fbu<- 1/(sig.fbu*sig.fbu)
sig.fbu ~ dunif(0,100)

tau.sgr.block<- 1/(sig.sgr.block*sig.sgr.block)
sig.sgr.block ~ dunif(0,100)
tau.fbp.block<- 1/(sig.fbp.block*sig.fbp.block)
sig.fbp.block ~ dunif(0,100)
tau.fbu.block<- 1/(sig.fbu.block*sig.fbu.block)
sig.fbu.block ~ dunif(0,100)



tau.sgr.plot<- 1/(sig.sgr.plot*sig.sgr.plot)
sig.sgr.plot ~ dunif(0,100)
tau.fbp.plot<- 1/(sig.fbp.plot*sig.fbp.plot)
sig.fbp.plot ~ dunif(0,100)
tau.fbu.plot<- 1/(sig.fbu.plot*sig.fbu.plot)
sig.fbu.plot ~ dunif(0,100)


tau.beta<- 1/(sig.beta*sig.beta)
sig.beta ~ dunif(0,20)
```

```
# model selection indices

for (j in 1:p){mindex[j] <- pow(2,j)}
modl <- 1 + inprod(gam, mindex)



}
```

S9. Parameter estimates and numerical diagnostics for the Bayesian hierarchical models fitted to canopy tree seedling growth rates and foliar biomass in the three forests in which deer culling was conducted

The tables below report the results of the analysis of canopy tree seedling height relative growth rates (SHRGRs) and the foliar biomass of palatable understorey species (FBP) and unpalatable understorey species (FBU) in the understory of the Waihaha, Waiotaka and Ruataniwha forests. The effect of the treatment (i.e. deer culling) relative to the non-treatment is given by the parameter β_5; the other parameters are as indicated in Table S9-1. $\hat{R}$ is the Brooks–Gelman–Rubin convergence statistic (Brooks and Gelman 1998), with values close to 1.0 indicating convergence of the Markov chain Monte Carlo chains. σ_γ, σ_δ and σ_ε are the random effects (standard deviations) due to block, plot-within-block and residual errors, respectively. Sample sizes for each analysis are provided in Tables 1 and 2 in the main text.

Table S9-1. Variables used in the analysis of canopy tree seedling height relative growth rates

Parameter	Variable	Units
β_1	Intercept	SHRGR
β_2	Light	%PAR
β_3	Landscape Index (LI)	degrees
β_4	Basal area (BA)	m^2 ha^{-1}
β_5	Treatment	binary

Table S9-2. Parameter estimates and numerical diagnostics from the JAGS model (equation 4) fitted to *Weinmannia racemosa* seedling height relative growth rates

W. racemosa seedlings were monitored in two forests in which deer culling was conducted (Waihaha and Waiotaka). Parameters are defined in Table S9-1 and sample sizes are given in Table 1 in the main text

Parameter	Mean	SD	2.5%	97.5%	$\hat{R}$
β_1	–0.009	0.094	–0.157	0.136	1.02
β_2	0.007	0.007	–0.008	0.021	1.00
β_3	0.003	0.009	–0.014	0.022	1.00
β_4	0.006	0.009	–0.012	0.024	1.00
β_5	0.002	0.136	–0.205	0.211	1.02
σ_γ	0.064	0.117	0.001	0.401	1.00
σ_δ	0.040	0.008	0.026	0.058	1.00
σ_ε	0.074	0.003	0.068	0.079	1.00

Table S9-3. Parameter estimates and numerical diagnostics from the JAGS model (equation 4) fitted to *Nothofagus fusca* seedling height relative growth rates

N. fusca seedlings were monitored in one forest in which deer culling was conducted (Waiotaka). Parameters are defined in Table S9-1 and sample sizes are given in Table 1 of the main text

Parameter	Mean	SD	2.5%	97.5%	$\hat{R}$
β_1	0.013	0.011	–0.008	0.035	1.00
β_2	–0.009	0.007	–0.024	0.005	1.00
β_3	–0.004	0.009	–0.024	0.014	1.00
β_4	–0.004	0.008	–0.019	0.011	1.00
β_5	0.016	0.017	–0.018	0.049	1.00
σ_δ	0.020	0.011	0.001	0.044	1.01
σ_ε	0.067	0.004	0.060	0.076	1.00

Table S9-4. Parameter estimates and numerical diagnostics from the JAGS model (equation 4) fitted to *Carpodetus serratus* seedling height relative growth rates

C. serratus seedlings were monitored in one forest in which deer culling was conducted (Waihaha). Parameters are defined in Table S9-1 and sample sizes are given in Table 1 of the main text

Parameter	Mean	SD	2.5%	97.5%	$\hat{R}$
β_1	0.026	0.019	–0.010	0.063	1.00
β_2	–0.004	0.012	–0.029	0.020	1.00
β_3	0.024	0.016	–0.009	0.055	1.00
β_4	–0.021	0.012	–0.045	0.003	1.00
β_5	0.054	0.032	–0.010	0.115	1.00
σ_δ	0.024	0.015	0.001	0.057	1.01
σ_ε	0.128	0.007	0.115	0.143	1.00

Table S9-5. Parameter estimates and numerical diagnostics from the JAGS model (equation 4) fitted to *Nothofagus solandri* var. *cliffortioides* seedling height relative growth rates

N. solandri var. *cliffortioides* seedlings were monitored in one forest in which deer culling was conducted (Ruataniwha). Parameters are defined in Table S9-1 and sample sizes are given in Table 1 of the main text

Parameter	Mean	SD	2.5%	97.5%	$\hat{R}$
β_1	0.040	0.005	0.030	0.049	1.00
β_2	0.006	0.003	0.001	0.012	1.00
β_3	0.003	0.003	–0.004	0.009	1.00
β_4	–0.003	0.003	–0.009	0.003	1.00
β_5	0.002	0.006	–0.010	0.015	1.00
σ_δ	0.024	0.002	0.020	0.029	1.00
σ_ε	0.067	0.001	0.066	0.068	1.00

Table S9-6. Parameter estimates and numerical diagnostics from the JAGS model (equation 4) fitted to *Nothofagus* spp. seedling height relative growth rates

Nothofagus spp. seedlings were monitored in two forests in which deer culling was conducted (Waiotaka and Ruataniwha). Parameters are defined in Table S9-1 and sample sizes are given in Table 1 of the main text

Parameter	Mean	SD	2.5%	97.5%	$\hat{R}$
β_1	0.028	0.131	–0.162	0.210	1.03
β_2	0.003	0.002	–0.002	0.007	1.00
β_3	0.001	0.003	–0.005	0.006	1.00
β_4	–0.004	0.003	–0.009	0.001	1.00
β_5	0.007	0.184	–0.254	0.277	1.02
σ_γ	0.081	0.167	0.003	0.537	1.00
σ_δ	0.024	0.002	0.019	0.028	1.00
σ_ε	0.067	0.001	0.066	0.068	1.00

Table S9-7. Parameter estimates and numerical diagnostics from the JAGS model (equation 4) fitted to all spp. seedling height relative growth rates

Seedlings were monitored in three forests in which deer culling was conducted (Waihaha, Waiotaka and Ruataniwha). Parameters are defined in Table S9-1 and sample sizes are given in Table 1 in the main text

Parameter	Mean	SD	2.5%	97.5%	$\hat{R}$
β_1	0.026	0.019	–0.011	0.062	1.00
β_2	0.003	0.002	–0.002	0.007	1.00
β_3	0.003	0.003	–0.002	0.009	1.00
β_4	0.000	0.003	–0.006	0.005	1.00
β_5	0.000	0.027	–0.053	0.052	1.00
σ_γ	0.025	0.018	0.006	0.074	1.00
σ_δ	0.030	0.003	0.025	0.036	1.00
σ_ε	0.069	0.001	0.068	0.070	1.00

Table S9-8. Variables used in the analysis of foliar biomass of palatable understorey species (FBP) and unpalatable understorey species (FBU)

Parameter	Variable	Units
β_1	Intercept	Log (g)
β_2	Light	%PAR
β_3	Landscape Index (LI)	degrees
β_4	Basal area (BA)	m^2 ha^{-1}
β_5	Treatment	binary

Table S9-9. Parameter estimates and numerical diagnostics from the JAGS model (equation 4) fitted to FBP

Parameters are defined in Table S9-8 and sample sizes are given in Table 2 in the main text

Parameter	Mean	SD	2.5%	97.5%	$\hat{R}$
β_1	1.210	0.699	–0.144	2.570	1.00
β_2	0.046	0.052	–0.057	0.147	1.00
β_3	0.119	0.052	0.016	0.221	1.00
β_4	–0.219	0.054	–0.325	–0.115	1.00
β_5	0.086	0.990	–1.850	1.900	1.00
σ_γ	0.996	0.711	0.399	2.650	1.00
σ_δ	0.794	0.040	0.718	0.876	1.00
σ_ε	0.837	0.019	0.801	0.874	1.00

Table S9-10. Parameter estimates and numerical diagnostics from the JAGS model (equation 4) fitted to FBU

Parameters are defined in Table S9-8 and sample sizes are given in Table 2 in the main text

Parameter	Mean	SD	2.5%	97.5%	$\hat{R}$
β_1	3.380	0.659	2.080	4.700	1.00
β_2	0.234	0.055	0.124	0.340	1.00
β_3	0.197	0.055	0.090	0.306	1.00
β_4	–0.104	0.057	–0.215	0.009	1.00
β_5	0.030	0.918	–1.790	1.830	1.00
σ_γ	0.965	0.606	0.384	2.570	1.00
σ_δ	0.824	0.042	0.744	0.911	1.00
σ_ε	0.928	0.021	0.889	0.970	1.00

Reference

Brooks, S., and Gelman, A. (1998). General methods for monitoring convergence of iterative simulations. *Journal of Computational and Graphical Statistics* **7**, 434–455.

S10. Parameter estimates, inclusion probabilities and numerical diagnostics for the Bayesian structural equation models fitted to data collected in the four forests

The tables below summarise the model-averaged parameter estimates (α_1, α_2 and $\beta_1 \ldots \beta_{11}$) and the relative importance of variables ($\gamma\alpha_1$, $\gamma\alpha_2$ and $\gamma\beta_1 \ldots \gamma\beta_{11}$) in the Bayesian structural equation model (equation 5) of the forest–deer system. Separate structural equation models were fitted to each canopy tree seedling species and to some combinations of species. $\hat{R}$ is the Brooks–Gelman–Rubin convergence statistic (Brooks and Gelman 1998), with values close to 1.0 indicating convergence of the Markov chain Monte Carlo chains. σ_γ, σ_δ and σ_ε are the random effects (standard deviations) due to block, plot-within-block and residual errors, respectively, for the seedling height relative growth rate (SHRGR) equation and the foliar biomass of palatable understorey species (FBP) and unpalatable understorey species (FBU) equations, respectively.

Table S10-1. Model-averaged parameter estimates, inclusion probabilities and diagnostics for the best structural equation model fitted to *Weinmannia racemosa*

Parameter	Mean	SD	2.5%	97.5%	$\hat{R}$
α_1	0.000	0.002	0.000	0.007	1.00
α_2	0.000	0.001	–0.003	0.000	1.00
β_1	0.000	0.002	0.000	0.005	1.00
β_2	0.000	0.002	–0.001	0.004	1.00
β_3	0.000	0.002	–0.001	0.006	1.00
β_4	–0.001	0.003	–0.009	0.001	1.00
β_5	0.060	0.087	–0.011	0.270	1.00
β_6	–0.017	0.055	–0.185	0.055	1.00
β_7	–0.082	0.112	–0.348	0.015	1.00

β_8	–0.108	0.145	–0.455	0.024	1.00
β_9	0.042	0.081	–0.030	0.265	1.00
β_{10}	0.019	0.066	–0.075	0.215	1.00
β_{11}	–0.158	0.159	–0.488	0.007	1.01
$\gamma\alpha_1$	0.104	0.305	0.000	1.000	1.01
$\gamma\alpha_2$	0.082	0.274	0.000	1.000	1.01
$\gamma\beta_1$	0.094	0.292	0.000	1.000	1.01
$\gamma\beta_2$	0.091	0.287	0.000	1.000	1.01
$\gamma\beta_3$	0.099	0.299	0.000	1.000	1.01
$\gamma\beta_4$	0.125	0.330	0.000	1.000	1.00
$\gamma\beta_5$	0.540	0.498	0.000	1.000	1.00
$\gamma\beta_6$	0.356	0.479	0.000	1.000	1.00
$\gamma\beta_7$	0.581	0.493	0.000	1.000	1.00
$\gamma\beta_8$	0.618	0.486	0.000	1.000	1.00
$\gamma\beta_9$	0.452	0.498	0.000	1.000	1.00
$\gamma\beta_{10}$	0.376	0.484	0.000	1.000	1.00
$\gamma\beta_{11}$	0.729	0.445	0.000	1.000	1.01
$\sigma_\varepsilon^{\mathrm{FBP}}$	0.515	0.018	0.481	0.551	1.00
$\sigma_\gamma^{\mathrm{FBP}}$	1.120	0.519	0.523	2.430	1.00
$\sigma_\delta^{\mathrm{FBP}}$	0.723	0.083	0.577	0.902	1.00
$\sigma_\varepsilon^{\mathrm{FBU}}$	0.449	0.016	0.420	0.481	1.00
$\sigma_\gamma^{\mathrm{FBU}}$	0.493	0.312	0.075	1.210	1.00

$\sigma_{\delta}^{\text{FBU}}$	0.918	0.095	0.749	1.120	1.00
$\sigma_{\varepsilon}^{\text{SGR}}$	0.070	0.002	0.066	0.075	1.00
$\sigma_{\gamma}^{\text{SGR}}$	0.016	0.015	0.001	0.048	1.00
$\sigma_{\delta}^{\text{SGR}}$	0.033	0.006	0.022	0.045	1.00

Table S10-2. Model-averaged parameter estimates, inclusion probabilities and diagnostics for the best structural equation model fitted to *Nothofagus menziesii*

Parameter	Mean	SD	2.5%	97.5%	$\hat{R}$
α_1	0.000	0.001	–0.004	0.000	1.00
α_2	0.000	0.001	–0.001	0.001	1.01
β_1	0.001	0.002	0.000	0.008	1.00
β_2	0.000	0.002	–0.006	0.001	1.01
β_3	–0.002	0.004	–0.016	0.000	1.00
β_4	0.000	0.001	–0.002	0.002	1.00
β_5	–0.018	0.054	–0.182	0.045	1.00
β_6	0.117	0.143	–0.012	0.441	1.00
β_7	–0.102	0.120	–0.367	0.007	1.00
β_8	–0.016	0.058	–0.194	0.063	1.00
β_9	–0.025	0.075	–0.252	0.067	1.00
β_{10}	0.050	0.116	–0.077	0.385	1.00
β_{11}	–0.113	0.148	–0.460	0.016	1.00
$\gamma\alpha_1$	0.086	0.280	0.000	1.000	1.01
$\gamma\alpha_2$	0.076	0.265	0.000	1.000	1.01

$\gamma\beta_1$	0.124	0.330	0.000	1.000	1.01
$\gamma\beta_2$	0.105	0.306	0.000	1.000	1.02
$\gamma\beta_3$	0.226	0.418	0.000	1.000	1.01
$\gamma\beta_4$	0.090	0.286	0.000	1.000	1.01
$\gamma\beta_5$	0.356	0.479	0.000	1.000	1.00
$\gamma\beta_6$	0.642	0.479	0.000	1.000	1.00
$\gamma\beta_7$	0.644	0.479	0.000	1.000	1.00
$\gamma\beta_8$	0.351	0.477	0.000	1.000	1.00
$\gamma\beta_9$	0.386	0.487	0.000	1.000	1.00
$\gamma\beta_{10}$	0.456	0.498	0.000	1.000	1.00
$\gamma\beta_{11}$	0.620	0.485	0.000	1.000	1.00
$\sigma_\varepsilon^{\text{FBP}}$	0.672	0.043	0.594	0.762	1.00
$\sigma_\gamma^{\text{FBP}}$	0.660	1.410	0.011	4.540	1.00
$\sigma_\delta^{\text{FBP}}$	0.632	0.109	0.442	0.868	1.00
$\sigma_\varepsilon^{\text{FBU}}$	0.602	0.041	0.529	0.688	1.00
$\sigma_\gamma^{\text{FBU}}$	2.020	5.490	0.027	18.100	1.01
$\sigma_\delta^{\text{FBU}}$	1.020	0.156	0.751	1.360	1.00
$\sigma_\varepsilon^{\text{SGR}}$	0.037	0.003	0.032	0.042	1.00
$\sigma_\gamma^{\text{SGR}}$	0.093	0.189	0.007	0.594	1.00
$\sigma_\delta^{\text{SGR}}$	0.031	0.007	0.018	0.047	1.00

Table S10-3. Model-averaged parameter estimates, inclusion probabilities and diagnostics for the best structural equation model fitted to *Nothofagus fusca*

Parameter	Mean	SD	2.5%	97.5%	$\hat{R}$
α_1	0.000	0.002	–0.004	0.003	1.01
α_2	0.001	0.004	0.000	0.013	1.02
β_1	0.000	0.002	–0.008	0.003	1.02
β_2	–0.001	0.004	–0.013	0.004	1.02
β_3	–0.001	0.003	–0.009	0.002	1.02
β_4	0.003	0.006	–0.001	0.022	1.03
β_5	–0.023	0.068	–0.248	0.026	1.01
β_6	–0.012	0.065	–0.211	0.066	1.02
β_7	–0.009	0.046	–0.154	0.043	1.01
β_8	0.023	0.080	–0.039	0.291	1.01
β_9	–0.005	0.041	–0.123	0.053	1.00
β_{10}	0.049	0.128	–0.032	0.456	1.01
β_{11}	–0.029	0.080	–0.289	0.025	1.01
$\gamma\alpha_1$	0.159	0.365	0.000	1.000	1.03
$\gamma\alpha_2$	0.259	0.438	0.000	1.000	1.03
$\gamma\beta_1$	0.189	0.391	0.000	1.000	1.03
$\gamma\beta_2$	0.223	0.416	0.000	1.000	1.03
$\gamma\beta_3$	0.195	0.396	0.000	1.000	1.03
$\gamma\beta_4$	0.323	0.468	0.000	1.000	1.04
$\gamma\beta_5$	0.428	0.495	0.000	1.000	1.05

$\gamma\beta_6$	0.400	0.490	0.000	1.000	1.04
$\gamma\beta_7$	0.377	0.485	0.000	1.000	1.04
$\gamma\beta_8$	0.425	0.494	0.000	1.000	1.04
$\gamma\beta_9$	0.367	0.482	0.000	1.000	1.04
$\gamma\beta_{10}$	0.476	0.499	0.000	1.000	1.03
$\gamma\beta_{11}$	0.448	0.497	0.000	1.000	1.04
$\sigma_{\varepsilon}^{\text{FBP}}$	0.628	0.031	0.571	0.693	1.00
$\sigma_{\gamma}^{\text{FBP}}$	0.496	0.432	0.030	1.610	1.00
$\sigma_{\delta}^{\text{FBP}}$	0.907	0.116	0.703	1.160	1.00
$\sigma_{\varepsilon}^{\text{FBU}}$	0.496	0.025	0.450	0.548	1.00
$\sigma_{\gamma}^{\text{FBU}}$	0.331	0.375	0.011	1.160	1.00
$\sigma_{\delta}^{\text{FBU}}$	1.020	0.120	0.810	1.280	1.00
$\sigma_{\varepsilon}^{\text{SGR}}$	0.061	0.003	0.055	0.068	1.00
$\sigma_{\gamma}^{\text{SGR}}$	0.022	0.022	0.001	0.073	1.00
$\sigma_{\delta}^{\text{SGR}}$	0.034	0.009	0.015	0.053	1.00

Table S10-4. Model-averaged parameter estimates, inclusion probabilities and diagnostics for the best structural equation model fitted to *Nothofagus solandri* var. *cliffortioides*

Parameter	Mean	SD	2.5%	97.5%	$\hat{R}$
α_1	0.000	0.001	0.000	0.002	1.00
α_2	0.002	0.002	0.001	0.006	1.00
β_1	0.002	0.003	0.000	0.009	1.00
β_2	0.000	0.002	–0.001	0.005	1.00
β_3	–0.001	0.002	–0.008	0.000	1.00
β_4	0.001	0.002	–0.001	0.006	1.00
β_5	–0.015	0.047	–0.172	0.020	1.08
β_6	0.033	0.073	–0.012	0.259	1.01
β_7	–0.024	0.068	–0.242	0.016	1.01
β_8	–0.005	0.038	–0.116	0.052	1.02
β_9	0.002	0.026	–0.043	0.063	1.02
β_{10}	0.024	0.065	–0.017	0.236	1.03
β_{11}	0.000	0.026	–0.058	0.056	1.03
$\gamma\alpha_1$	0.157	0.364	0.000	1.000	1.00
$\gamma\alpha_2$	0.652	0.476	0.000	1.000	1.00
$\gamma\beta_1$	0.522	0.500	0.000	1.000	1.00
$\gamma\beta_2$	0.250	0.433	0.000	1.000	1.00
$\gamma\beta_3$	0.378	0.485	0.000	1.000	1.00
$\gamma\beta_4$	0.271	0.445	0.000	1.000	1.00
$\gamma\beta_5$	0.501	0.500	0.000	1.000	1.00

$\gamma\beta_6$	0.576	0.494	0.000	1.000	1.00
$\gamma\beta_7$	0.527	0.499	0.000	1.000	1.00
$\gamma\beta_8$	0.483	0.500	0.000	1.000	1.00
$\gamma\beta_9$	0.447	0.497	0.000	1.000	1.00
$\gamma\beta_{10}$	0.536	0.499	0.000	1.000	1.00
$\gamma\beta_{11}$	0.447	0.497	0.000	1.000	1.00
$\sigma_\varepsilon^{\text{FBP}}$	0.548	0.005	0.539	0.558	1.00
$\sigma_\gamma^{\text{FBP}}$	1.410	4.720	0.027	8.560	1.00
$\sigma_\delta^{\text{FBP}}$	1.100	0.095	0.936	1.300	1.00
$\sigma_\varepsilon^{\text{FBU}}$	0.515	0.004	0.507	0.524	1.00
$\sigma_\gamma^{\text{FBU}}$	0.868	2.100	0.013	6.370	1.00
$\sigma_\delta^{\text{FBU}}$	0.945	0.082	0.800	1.120	1.00
$\sigma_\varepsilon^{\text{SGR}}$	0.067	0.001	0.066	0.068	1.00
$\sigma_\gamma^{\text{SGR}}$	0.196	0.377	0.025	1.160	1.00
$\sigma_\delta^{\text{SGR}}$	0.024	0.003	0.019	0.029	1.00

Table S10-5. Model-averaged parameter estimates, inclusion probabilities and diagnostics for the best structural equation model fitted to *Carpodetus serratus*

Parameter	Mean	SD	2.5%	97.5%	$\hat{R}$
α_1	0.002	0.006	–0.004	0.020	1.00
α_2	0.001	0.005	–0.007	0.015	1.00
β_1	–0.001	0.005	–0.016	0.007	1.00
β_2	0.003	0.008	–0.006	0.028	1.00
β_3	–0.002	0.007	–0.023	0.004	1.00
β_4	0.000	0.005	–0.013	0.008	1.00
β_5	–0.010	0.055	–0.177	0.060	1.00
β_6	–0.011	0.064	–0.201	0.069	1.00
β_7	–0.013	0.064	–0.213	0.062	1.01
β_8	0.004	0.050	–0.082	0.136	1.00
β_9	–0.022	0.069	–0.245	0.038	1.01
β_{10}	0.083	0.158	–0.024	0.531	1.01
β_{11}	–0.010	0.056	–0.186	0.064	1.00
$\gamma\alpha_1$	0.289	0.453	0.000	1.000	1.00
$\gamma\alpha_2$	0.264	0.441	0.000	1.000	1.00
$\gamma\beta_1$	0.264	0.441	0.000	1.000	1.00
$\gamma\beta_2$	0.320	0.467	0.000	1.000	1.00
$\gamma\beta_3$	0.310	0.463	0.000	1.000	1.00
$\gamma\beta_4$	0.256	0.436	0.000	1.000	1.00
$\gamma\beta_5$	0.443	0.497	0.000	1.000	1.00

$\gamma\beta_6$	0.448	0.497	0.000	1.000	1.00
$\gamma\beta_7$	0.456	0.498	0.000	1.000	1.00
$\gamma\beta_8$	0.434	0.496	0.000	1.000	1.00
$\gamma\beta_9$	0.476	0.499	0.000	1.000	1.00
$\gamma\beta_{10}$	0.601	0.490	0.000	1.000	1.00
$\gamma\beta_{11}$	0.449	0.497	0.000	1.000	1.00
$\sigma_\varepsilon^{\text{FBP}}$	0.631	0.039	0.560	0.713	1.00
$\sigma_\gamma^{\text{FBP}}$	0.631	1.050	0.019	2.900	1.00
$\sigma_\delta^{\text{FBP}}$	0.834	0.144	0.596	1.160	1.00
$\sigma_\varepsilon^{\text{FBU}}$	0.654	0.041	0.581	0.739	1.00
$\sigma_\gamma^{\text{FBU}}$	0.819	1.510	0.021	3.820	1.00
$\sigma_\delta^{\text{FBU}}$	0.769	0.146	0.521	1.090	1.00
$\sigma_\varepsilon^{\text{SGR}}$	0.133	0.008	0.119	0.148	1.00
$\sigma_\gamma^{\text{SGR}}$	0.109	0.187	0.016	0.448	1.01
$\sigma_\delta^{\text{SGR}}$	0.021	0.014	0.001	0.054	1.05

Table S10-6. Model-averaged parameter estimates, inclusion probabilities and diagnostics for the best structural equation model fitted to *Nothofagus* spp.

Parameter	Mean	SD	2.5%	97.5%	$\hat{R}$
α_1	0.000	0.000	0.000	0.000	1.03
α_2	0.002	0.002	0.001	0.006	1.00
β_1	0.000	0.001	0.000	0.003	1.00
β_2	0.000	0.000	0.000	0.000	1.02
β_3	–0.001	0.003	–0.008	0.000	1.00
β_4	0.000	0.001	0.000	0.005	1.01
β_5	–0.050	0.060	–0.184	0.000	1.00
β_6	0.063	0.073	–0.003	0.223	1.00
β_7	–0.167	0.087	–0.328	–0.001	1.00
β_8	–0.023	0.055	–0.178	0.053	1.00
β_9	–0.006	0.026	–0.085	0.040	1.00
β_{10}	0.174	0.074	0.001	0.318	1.00
β_{11}	–0.040	0.058	–0.183	0.010	1.00
$\gamma\alpha_1$	0.015	0.120	0.000	0.000	1.01
$\gamma\alpha_2$	0.436	0.496	0.000	1.000	1.00
$\gamma\beta_1$	0.045	0.208	0.000	1.000	1.00
$\gamma\beta_2$	0.018	0.132	0.000	0.000	1.01
$\gamma\beta_3$	0.221	0.415	0.000	1.000	1.00
$\gamma\beta_4$	0.059	0.236	0.000	1.000	1.00
$\gamma\beta_5$	0.562	0.496	0.000	1.000	1.00

$\gamma\beta_6$	0.583	0.493	0.000	1.000	1.00
$\gamma\beta_7$	0.918	0.274	0.000	1.000	1.01
$\gamma\beta_8$	0.379	0.485	0.000	1.000	1.00
$\gamma\beta_9$	0.255	0.436	0.000	1.000	1.00
$\gamma\beta_{10}$	0.970	0.169	0.000	1.000	1.04
$\gamma\beta_{11}$	0.476	0.499	0.000	1.000	1.00
$\sigma_{\varepsilon}^{\text{FBP}}$	0.540	0.005	0.532	0.549	1.00
$\sigma_{\gamma}^{\text{FBP}}$	0.740	0.357	0.299	1.630	1.00
$\sigma_{\delta}^{\text{FBP}}$	0.923	0.058	0.816	1.040	1.00
$\sigma_{\varepsilon}^{\text{FBU}}$	0.516	0.004	0.507	0.524	1.00
$\sigma_{\gamma}^{\text{FBU}}$	0.404	0.225	0.092	0.965	1.00
$\sigma_{\delta}^{\text{FBU}}$	0.863	0.056	0.760	0.980	1.00
$\sigma_{\varepsilon}^{\text{SGR}}$	0.066	0.001	0.065	0.067	1.00
$\sigma_{\gamma}^{\text{SGR}}$	0.037	0.020	0.018	0.077	1.00
$\sigma_{\delta}^{\text{SGR}}$	0.023	0.002	0.019	0.027	1.00

Table S10-7. Model-averaged parameter estimates, inclusion probabilities and diagnostics for the best structural equation model fitted to all spp.

Parameter	Mean	SD	2.5%	97.5%	$\hat{R}$
α_1	0.000	0.000	0.000	0.001	1.01
α_2	0.001	0.002	0.000	0.005	1.00
β_1	0.000	0.001	0.000	0.000	1.01
β_2	0.000	0.000	0.000	0.000	1.00
β_3	0.000	0.001	0.000	0.000	1.03
β_4	0.000	0.001	0.000	0.005	1.00
β_5	–0.014	0.030	–0.099	0.010	1.00
β_6	0.013	0.032	–0.019	0.108	1.01
β_7	–0.158	0.057	–0.264	–0.028	1.00
β_8	–0.028	0.052	–0.166	0.025	1.04
β_9	–0.004	0.020	–0.065	0.030	1.01
β_{10}	0.173	0.053	0.066	0.274	1.01
β_{11}	–0.046	0.058	–0.176	0.000	1.01
$\gamma\alpha_1$	0.032	0.175	0.000	1.000	1.00
$\gamma\alpha_2$	0.202	0.402	0.000	1.000	1.00
$\gamma\beta_1$	0.027	0.162	0.000	1.000	1.00
$\gamma\beta_2$	0.014	0.118	0.000	0.000	1.00
$\gamma\beta_3$	0.028	0.165	0.000	1.000	1.01
$\gamma\beta_4$	0.062	0.240	0.000	1.000	1.00
$\gamma\beta_5$	0.303	0.460	0.000	1.000	1.00

$\gamma\beta_6$	0.289	0.453	0.000	1.000	1.01
$\gamma\beta_7$	0.980	0.142	1.000	1.000	1.09
$\gamma\beta_8$	0.397	0.489	0.000	1.000	1.01
$\gamma\beta_9$	0.202	0.401	0.000	1.000	1.00
$\gamma\beta_{10}$	0.990	0.100	1.000	1.000	1.11
$\gamma\beta_{11}$	0.519	0.500	0.000	1.000	1.01
$\sigma_{\varepsilon}^{FBP}$	0.470	0.004	0.463	0.478	1.00
σ_{γ}^{FBP}	1.180	0.394	0.668	2.160	1.00
σ_{δ}^{FBP}	0.768	0.041	0.693	0.854	1.00
$\sigma_{\varepsilon}^{FBU}$	0.496	0.004	0.488	0.503	1.00
σ_{γ}^{FBU}	0.603	0.217	0.314	1.140	1.00
σ_{δ}^{FBU}	0.796	0.044	0.715	0.887	1.00
$\sigma_{\varepsilon}^{SGR}$	0.068	0.001	0.067	0.069	1.00
σ_{γ}^{SGR}	0.030	0.010	0.017	0.055	1.00
σ_{δ}^{SGR}	0.026	0.002	0.022	0.031	1.00

Reference

Brooks, S., and Gelman, A. (1998). General methods for monitoring convergence of iterative simulations. *Journal of Computational and Graphical Statistics* **7**, 434–455.