Frog and reptile communities and functional groups over a land-use gradient in a coastal tropical forest landscape of high richness and endemicity

Morgan J. Trimble and Rudi J. van Aarde

Electronic Supplemental Material:

Appendix S1

Pitfall traps:

Pitfall traps were dark plastic 20 liter buckets dug into the ground such that the rim of the bucket was flush with ground level. Several small drainage holes (0.5 cm) were drilled in the bottom of each bucket. Each trap array contained seven pitfall buckets, one at the central point, and two along each arm. Bucket lids, to protect buckets from sun, rain, and predators, were suspended 10 cm over buckets using wire stands. 3 cm of soil and leaf litter were placed inside buckets along with a wet sponge to maintain a suitable environment for trapped organisms. Sampling effort in pitfall traps was 35 trap nights per array, 210 trap nights per vegetation type, and 1050 trap nights in the overall study.

Funnel traps:

We constructed funnel traps out of 0.5 cm wire mesh following Fisher et al. (2008). Funnel traps were cylinders 90 cm long and 14 cm in diameter with inverted cone funnels with 4 cm openings inserted in each end. Funnel traps were installed along each side of each drift fence arm with soil built up around the bottom to guide amphibians and reptiles moving along the fence into the funnel. Funnels were covered with leaves and vegetation to provide shade for trapped organisms. Sampling effort in funnel traps was 30 trap nights per array, 180 trap nights per vegetation type, and 900 trap nights in the overall study.

Cover boards:

Four cover boards were placed on the ground in an array 10 meters beyond the final pitfall bucket of the northern most pointing drift fence arm. The boards were 60 cm square sheets of 2 cm plywood.

PVC pipe traps:

Pipe trap were mounted on a tree nearest the cover boards at each array point. Each pipe trap array consisted of four, 60 cm long, opaque white PVC pipes. We inserted two pipes, one of 16 mm internal diameter and one of 44 mm internal diameter, into the ground near the base of a tree. We capped one end of another two pipes, one of each of the two diameters, fixed them together with cable ties, and hung them vertically from the tree trunk such that the open end was at a height of 2 m. The caps allowed retention of standing water in the bottom of the hanging pipes, and we drilled a hole in the pipes 15 cm from the bottom to prevent the pipes from totally filling with water (following recomendations in Boughton, Staiger & Franz, 2000). We installed pipes on a variety of tree species with circumference at breast height ranging from 10 cm to 200 cm (mean 53.7 cm, standard deviation 41.2 cm). In forest and degraded forest, we commonly hung pipes on White Stinkwood *Celtis africana* and Horsewood *Clausena anisata* trees. In acacia woodland, pipes were hung on Sweet Thorn *Acacia karroo* while we used eucalyptus trees in woodlots. At five of the six sugar cane cultivation array sites, there were no trees nearby, so all four pipes were inserted into the ground. We hung pipes in a dead tree of unknown species at one cultivation site.

Acoustic sampling:

Automated acoustic recordings were made at each site with Song Meter SM2+ Terrestrial Acoustic Recorders (manufactured by Wildlife Acoustics, Concord, Massachusetts). Recorders were mounted to a tree 1 m off the ground, within a 15 m radius of the center bucket of the array, and set to record at a sample rate of 44,100 Hz for 5 minutes every hour, on the hour, for a 24-hour period. Acoustic detection depends on the power of each species' call, but estimates suggest that calling amphibians will be picked up by audio recorders over a 50 m radius (Hilje & Mitchell Aide, 2012). We analyzed audio files with Raven Pro version 1.4 software (Bioacoustic

Research Program, Cornell Lab of Ornithology, Ithaca, New York) to visualize spectrograms concurrently to listening to recordings. Calling amphibians were identified by comparison with species specific spectrograms and audio recordings provided in du Preez and Carruthers (2009). Overall, we analyzed 720 5-min recordings, or 120 min per site.

Active search:

One active search was carried out per sampling array, and all searches were carried out by the same individual expert observer. Each search was performed during daylight hours and lasted 30 min, in which the observer searched an area extending roughly 50 m from the central pitfall bucket of each array. The observer searched the area at will, focusing on particular areas one might expect to encounter herpetofauna, e.g. under rocks, on trees, in fallen logs, and in leaf litter. All amphibian and reptile species identified visually by the observer were recorded. Active searchers were employed to identify relatively obvious species that were unlikely to be trapped by other means, e.g. lizards living on trees, yet we limited their use to one search per array to avoid introducing unnecessary bias due to differing detection probabilities among different vegetation types (see Buckland *et al.*, 2001).

Incidental recordings:

We recorded species found when installing or removing trap arrays, which was a relatively standardized effort. For the most part, species found included fossorial species caught when digging holes for the pitfalls or trenches for the drift fences.

Environmental variables:

We measured climatic and structural environmental variables to characterize study sites. At each sampling array, we used HOBO data loggers mounted on rods 20cm from the ground to record temperature every 10 minutes for the duration of the five days that each trapping array was active. We then calculated a mean temperature for each array and the range in degrees from the minimum and maximum temperature recorded on each data logger. We recorded structural variables including canopy cover, canopy height, litter depth, litter cover, and herb cover. Canopy cover was measured at three points, each 5 m away from the center bucket of the trapping array, by visually estimating coverage when looking through a 10 cm tube of 4 cm diameter. Canopy height was assigned to classes (0-2 m, >2-4 m, >4-6 m, >6-8 m, and >8 m). The other structural variables were measured in a 1m x 1 m PVC pipe frame at each of the three sampling points. Litter depth was measured to the nearest cm with a ruler at the center of the frame, while litter cover (woody debris and leaves) and herb cover (herbaceous vegetation excluding grasses and trees) were visually estimated to the nearest 5%. For each array, we averaged the three values for each variable to achieve a single value. To calculate soil pH, a trowel-full of soil was collected from each of the three sampling points at each array and mixed in a bag. We oven-dried 50 g of each soil sample for 24 hours at 70℃. We combined 15 ml of each dried soil sample with 75 ml distilled water, shook for 1 min, let sit for 1 hour, shook again, and measured pH with a Consort c562 meter.

Geographic gradients

For each array point, we measured distance to the coast and distance along a southwest—northeast gradient according to distance from the most southwesterly array point. We assessed whether vegetation types differed significantly in coastal distance or southwest—northeast gradient with ANOVA. Vegetation types differed significantly in their distance from the coast ($F_{4,25}$=7.40, p<0.01), and Tukey's multiple comparison test indicated significant differences between plantation points and others. Besides plantations, the distance from the coast of other vegetation types did not differ significantly from each other. Contrastingly, there was no significant difference in southwest—northeast gradient among vegetation types ($F_{4,25}$=0.86, p=0.50). Thus, we assessed if coastal distance of array points effected observed richness (species per array) and abundance (individuals per array) with Poisson generalized linear modeling (GLM) (z-values) or quasi-Poisson GLM (t-values) to account for overdispersion (Zuur et al., 2009). Distance from coast was not a significant predictor for frog richness (z-value=1.42, $p=0.16$), frog abundance ($\Phi=18.99$, t-value=0.14, $p=0.89$), reptile richness (z-value=0.65, $p=0.51$), or reptile abundance ($\Phi=1.22$, t-value=0.73, $p=0.47$).

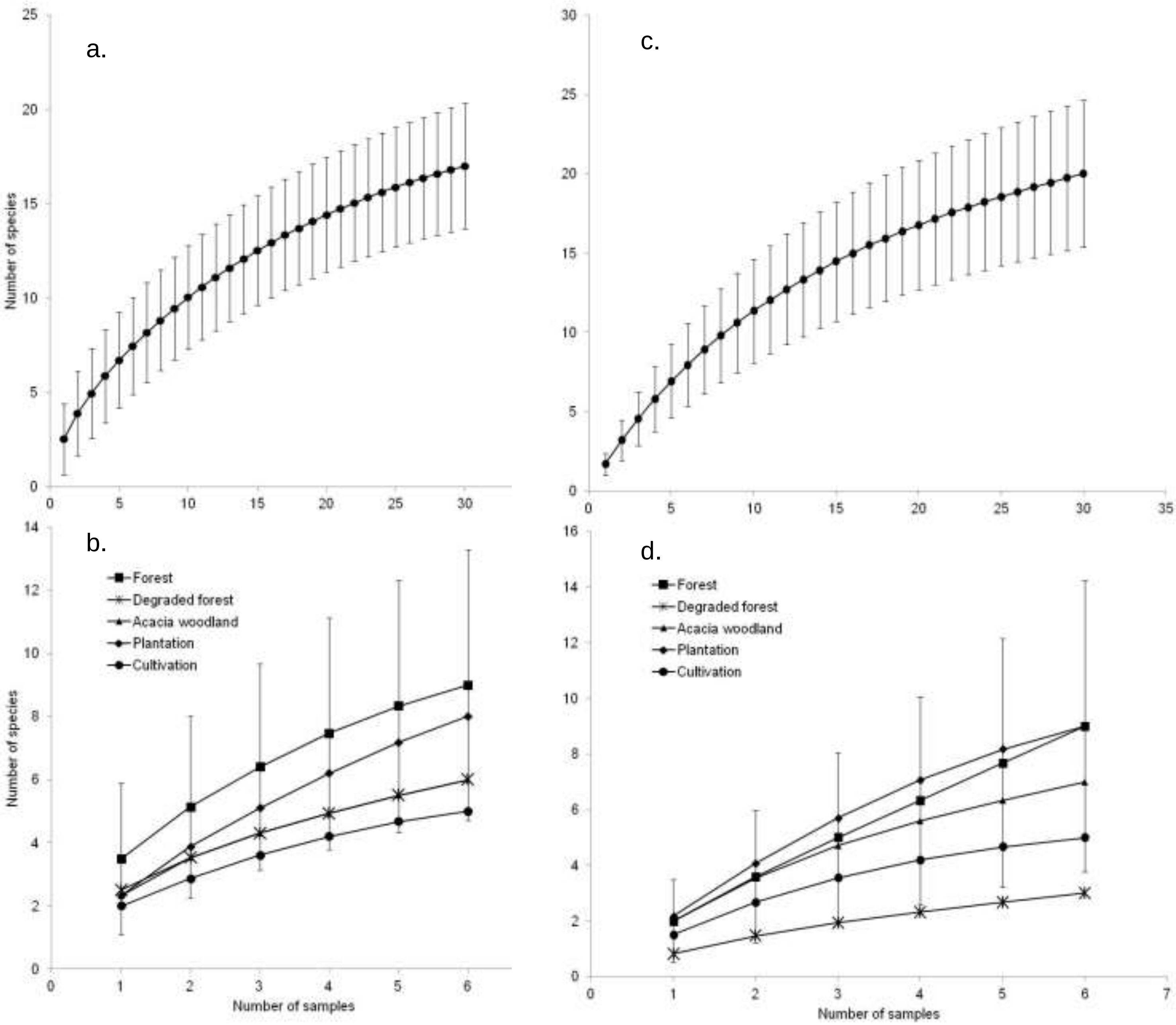

Fig. S2. Species accumulation curves for (a) the total frog dataset, (b) frog samples grouped by vegetation type, (c) the total reptile dataset, and (d) reptile samples grouped by vegetation type. Error bars represent 95% CI and in (b) and (d) are shown only for forest.

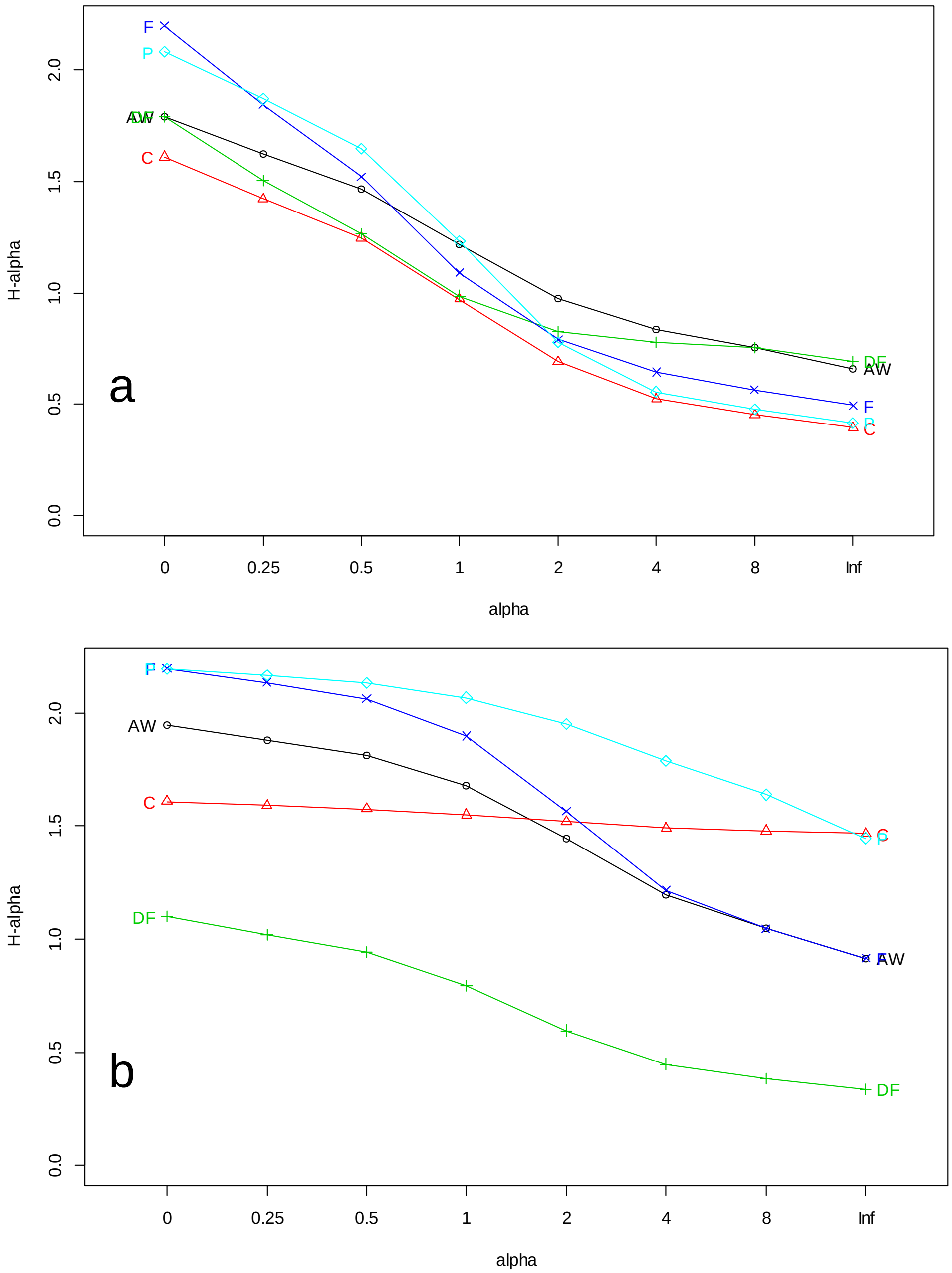

Fig. S3. Rényi diversity profiles for (a) frogs and (b) reptiles in different vegetation types (dark blue is forest (F); green is degraded forest (DF); black is acacia woodland (AW), light blue is plantation (P), red is cultivation (C). Rényi diversity profiles are calculated with the formula $H_\alpha=\ln(\Sigma\, p_i^{\alpha}) / (1-\alpha)$, where H_α is the diversity value, p_i values are the proportions of each species (which are taken to the exponent α and summed for all species recorded), and α is a parameter taken from 0 to infinity to generate the profile (Kindt & Coe, 2005). Values of H_α reflect species richness at α=0, are equivalent to the Shannon diversity index at α=1, and yield the logarithm of the reciprocal Simpson diversity index at α=2. Profiles indicate that frog diversity is lowest in cultivation, and reptile diversity is lowest in degraded forest and highest in plantation. The remaining vegetation types cannot be ranked definitively as their Rényi diversity profiles overlap.

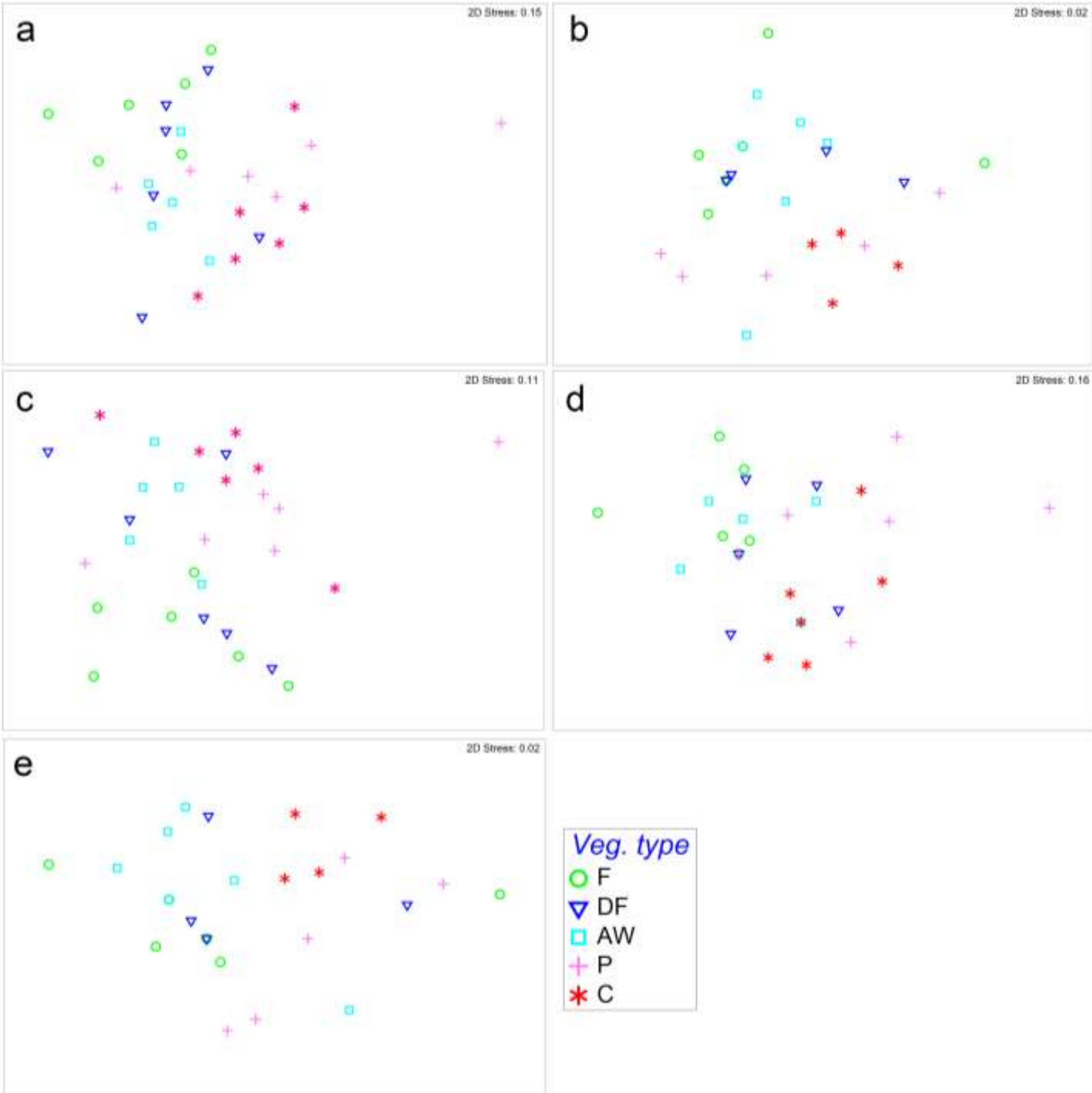

Fig. S4. Non-metric multidimensional scaling ordination of Bray Curtis similarities based on square-root-transformed (a) frog and (b) reptile abundance data and (c) raw frog abundance, (d) frog incidence, and (e) raw reptile abundance data. Symbols represent samples taken at 30 trapping array sites across five vegetation types (F = forest, DF = degraded forest, AW = acacia woodland, P = plantation, C = cultivation), and clustering indicates similar community composition among sites. One array site for frogs and four array sites for reptiles were not plotted because they were outliers with zero captures.

Table S1. Analysis of similarity (ANOSIM) results comparing frog and reptile community composition among vegetation types based on Bray Curtis similarity of raw abundance data for frogs and reptiles and incidence data for frogs including species identified from audio recordings.

Vegetation type comparison	**Frogs**				**Reptiles**	
	Abundance data (Global R=0.158, p=0.007)		**Incidence data (Global R=0.146, p=0.005)**		**Abundance data (Global R=0.193, p=0.001)**	
	R statistic [a]	**p [b]**	**R statistic [a]**	**p [b]**	**R statistic [a]**	**p [b]**
Forest–degraded forest	-0.01	0.45	0.01	0.44	-0.06	0.99
Forest–acacia woodland	0.30	0.01*	-0.03	0.61	0.14	0.11
Forest–plantation	0.28	<0.05*	0.26	<0.05*	0.24	<0.05*
Forest–cultivation	0.66	<0.01**	0.58	<0.01**	0.38	<0.01**
Degraded forest–acacia woodland	0.02	0.30	-0.07	0.80	0.09	0.20
Degraded forest–plantation	-0.03	0.55	0.17	0.09	0.18	0.05
Degraded forest–cultivation	0.14	0.10	0.21	0.07	0.28	<0.05*
Acacia woodland–plantation	0.12	0.08	0.08	0.17	0.30	<0.01**
Acacia woodland–cultivation	0.08	0.17	0.14	0.10	0.34	<0.01**
Plantation–cultivation	0.11	0.09	0.22	<0.05*	0.09	0.18

[a] ANOSIM generates an R statistic ranging from -1 (where similarities across different vegetation types are higher than within types) to 1 (where similarities within types are higher than between types) (Clarke & Gorley, 2001).
[b] Significance of each comparison is indicated by $*p \leq 0.05$, $** p \leq 0.01$, $*** p \leq 0.001$.

Table S2. Top selected models ($\Delta_i < 4$) relating environmental variables to (a) frog species richness, (b) frog abundance, (c) reptile species richness, (d) reptile abundance, and to abundance of functional groups (e) F1, (f) F2, (g) F3, (h) F4, (i) R1, (j) R2, (k) R3, and (l) R4 (D^2 = deviance explained by global models, VIF = variance inflation factor of global model, Par. = number of parameters in the model; LL = log-likelihood; AICc = Akaike's corrected information criterion; QAICc = Quasi-AICc; Δ_i = AICc or QAICc difference from best model; w_i = Akaike weights, the normalized relative likelihood of the model given the data; see Tables 1 and 4 for functional group composition and descriptions).

a) Frog species richness including audio (D^2=0.32; VIF=1)

Variables	**Par.**	**LL**	**AICc**	Δ_i	w_i
Litter cover	2	-51.62	107.69	0.00	0.16
Herb cover + Litter cover	3	-50.77	108.46	0.77	0.11
Null	1	-53.29	108.73	1.05	0.10
Litter cover + Range temp.	3	-51.20	109.32	1.63	0.07
Mean temp	2	-52.64	109.73	2.04	0.06
Litter cover + Litter depth	3	-51.49	109.90	2.21	0.05
Litter cover + Mean temp.	3	-51.56	110.05	2.37	0.05
Litter cover + Soil p H	3	-51.57	110.07	2.38	0.05
Herb cover + Litter cover + Mean temp.	4	-50.38	110.36	2.68	0.04
Herb cover + Mean temp.	3	-51.73	110.38	2.70	0.04
Herb cover	2	-53.13	110.71	3.03	0.04
Herb cover + Litter cover + Range temp.	4	-50.60	110.79	3.11	0.03
Litter depth	2	-53.18	110.81	3.12	0.03
Soil pH	2	-53.22	110.89	3.20	0.03
Range temp	2	-53.27	110.99	3.30	0.03
Herb cover + Litter cover + Litter depth	4	-50.76	111.12	3.43	0.03
Herb cover + Litter cover + Soil pH	4	-50.77	111.13	3.45	0.03
Litter cover + Mean temp. + Range temp.	4	-50.97	111.54	3.85	0.02

b) Frog abundance (D^2=0.64; VIF=5.59)

Variables	**Par.**	**LL**	**QAICc**	Δ_i	w_i
Herb cover + Mean temp. + Soil pH	4	-128.24	58.36	0.00	0.54
Herb cover + Litter cover + Mean temp. + Soil pH	5	-125.19	60.42	2.06	0.19
Herb cover + Litter depth + Mean temp. + Soil pH	5	-127.40	61.21	2.85	0.13
Herb cover + Mean temp. + Range temp. + Soil pH	5	-127.41	61.21	2.86	0.13

c) Reptile richness (D^2=0.06; VIF=1)

Variables	**Par.**	**LL**	**AICc**	Δ_i	w_i
Null	1	-46.18	94.51	0	0.31
Litter cover	2	-45.95	96.34	1.82	0.12

Range temp.	2	-46.04	96.53	2.01	0.11
Herb cover	2	-46.13	96.71	2.2	0.1
Soil pH	2	-46.14	96.73	2.22	0.1
Litter depth	2	-46.16	96.76	2.25	0.1
Mean temp.	2	-46.18	96.81	2.3	0.1
Litter cover + Litter depth	3	-45.69	98.31	3.8	0.05

d) Reptile abundance (D^2 =0.10; VIF=1.33)

Variables	**Par.**	**LL**	**QAICc**	Δ_i	w_i
Null	1	-55.15	87.08	0.00	0.32
Range temp.	2	-54.85	89.11	2.03	0.12
Litter cover	2	-54.91	89.20	2.12	0.11
Herb cover	2	-54.91	89.20	2.13	0.11
Soil pH	2	-54.96	89.28	2.20	0.11
Mean temp.	2	-55.11	89.49	2.41	0.10
Litter depth	2	-55.14	89.54	2.47	0.09
Range temp. + Soil pH	3	-54.30	90.96	3.88	0.05

e) Functional group F1 (D^2= 0.40; VIF=1.70)

Variables	**Par.**	**LL**	**QAICc**	Δ_i	w_i
Herb cover	2	-41.82	56.11	0.00	0.13
Herb cover + Mean temp.	3	-39.79	56.41	0.30	0.11
Herb cover + Litter cover + Mean temp.	4	-37.35	56.43	0.32	0.11
Herb cover + Soil pH	3	-40.06	56.73	0.61	0.10
Herb cover + Mean temp. + Soil pH	4	-37.65	56.78	0.67	0.09
Herb cover + Litter cover	3	-41.10	57.95	1.84	0.05
Herb cover + Mean temp. + Range temp. + Soil pH	5	-35.97	57.96	1.85	0.05
Herb cover + Litter cover + Mean temp. + Soil pH	5	-36.02	58.02	1.91	0.05
Herb cover + Range temp.	3	-41.81	58.78	2.67	0.03
Herb cover + Litter depth	3	-41.82	58.79	2.68	0.03
Herb cover + Litter depth + Mean temp.	4	-39.70	59.20	3.09	0.03
Herb cover + Mean temp. + Range temp.	4	-39.72	59.23	3.11	0.03
Herb cover + Litter cover + Soil pH	4	-39.72	59.23	3.11	0.03
Herb cover + Litter cover + Litter depth + Mean temp.	5	-37.13	59.33	3.22	0.03
Herb cover + Range temp. + Soil pH	4	-39.88	59.41	3.30	0.03
Litter cover	2	-44.66	59.46	3.35	0.02
Herb cover + Liter cover + Mean temp. + Range Temp.	5	-37.25	59.47	3.35	0.02
Herb cover + Litter depth + Soil pH	4	-40.04	59.60	3.49	0.02
Herb cover + Litter depth + Mean temp. Soil pH	5	-37.61	59.89	3.78	0.02

f) Functional group F2 (D^2= 0.67; VIF=5.15)

Variables	**Par.**	**LL**	**QAICc**	Δ_i	w_i
Litter cover + Mean temp. + Soil pH	4	-99.82	51.23	0.00	0.27
Herb cover + Litter cover + Mean temp. + Soil pH	5	-92.10	51.39	0.16	0.25
Litter cover + Litter depth + Mean temp. + Soil pH	5	-97.71	53.56	2.33	0.08
Mean temp. + Soil pH	3	-114.03	53.84	2.61	0.07
Herb cover + Mean temp. + Soil pH	4	-106.88	53.97	2.74	0.07
Litter cover + Mean temp. + Range temp. + Soil pH	5	-99.54	54.27	3.04	0.06
Mean temp. + Range temp. + Soil pH	4	-108.21	54.49	3.26	0.05

Herb cover + Mean temp. + Range temp. + Soil pH	5	-100.49	54.64	3.41	0.05
Herb cover + Litter cover + Litter depth + Mean temp. + Soil pH	6	-91.81	54.71	3.48	0.05
Herb cover + Litter cover + Mean temp. + Range temp. + Soil pH	6	-92.03	54.80	3.57	0.05

g) Functional group F3 (D^2=0.56; VIF=2.35)

Variables	**Par.**	**LL**	**QAICc**	Δ_i	w_i
Herb cover + Mean temp. + Soil pH	4	-77.11	78.11	0.00	0.61
Herb cover + Litter cover + Mean temp. + Soil pH	5	-77.05	81.21	3.10	0.13
Herb cover + Litter depth + Mean temp. + Soil pH	5	-77.08	81.23	3.13	0.13
Herb cover + Mean temp. + Range temp. + Soil pH	5	-77.10	81.25	3.14	0.13

h) Functional group F4 (D^2=0.34; VIF=1.59)

Variables	**Par.**	**LL**	**QAICc**	Δ_i	w_i
Litter depth	2	-15.88	36.20	0.00	0.20
Litter depth + Soil pH	3	-15.18	37.28	1.07	0.12
Litter cover + Litter depth	3	-15.36	37.65	1.44	0.10
Litter depth + Range temp.	3	-15.62	38.17	1.96	0.08
Herb cover + Litter depth	3	-15.75	38.42	2.21	0.07
Litter depth + Mean temp.	3	-15.85	38.61	2.41	0.06
Litter cover	2	-17.21	38.85	2.65	0.05
Litter cover + Litter depth + Soil pH	4	-14.72	39.04	2.83	0.05
Litter cover + Soil pH	3	-16.07	39.06	2.85	0.05
Range temp.	2	-17.60	39.65	3.45	0.04
Herb cover + Litter depth + Soil pH	4	-15.12	39.84	3.63	0.03
Litter depth + Range temp. + Soil pH	4	-15.16	39.91	3.71	0.03
Litter depth + Mean temp. + Soil pH	4	-15.17	39.95	3.74	0.03
Litter cover + Range temp.	3	-16.53	39.98	3.78	0.03
Litter cover + Litter depth + Range temp.	4	-15.22	40.05	3.84	0.03
Herb cover + Litter cover + Litter depth	4	-15.24	40.09	3.88	0.03

i) Functional group R1 (D^2=0.52; VIF=1)

Variables	**Par.**	**LL**	**AICc**	Δ_i	w_i
Litter cover	2	-11.43	27.30	0.00	0.06
Litter cover + Mean temp.	3	-10.27	27.46	0.16	0.06
Herb cover + Litter cover	3	-10.35	27.62	0.32	0.05
Null	1	-12.75	27.65	0.35	0.05
Range temp.	2	-11.85	28.14	0.84	0.04
Litter depth	2	-11.87	28.18	0.88	0.04
Herb cover + Range temp.	3	-10.67	28.26	0.97	0.04
Litter cover + Mean temp. + Range temp.	4	-9.38	28.36	1.06	0.04
Herb cover + Litter depth	3	-10.80	28.52	1.22	0.03
Litter cover + Litter depth + Mean temp.	4	-9.46	28.53	1.23	0.03
Mean temp. + Range temp.	3	-11.00	28.92	1.62	0.03
Herb cover + Litter cover + Mean temp.	4	-9.72	29.03	1.74	0.03
Herb cover + Litter cover + Soil pH	4	-9.72	29.05	1.75	0.03
Herb cover + Litter cover + Litter depth	4	-9.80	29.20	1.90	0.02
Herb cover + Litter cover + Range temp.	4	-9.82	29.23	1.94	0.02
Herb cover	2	-12.40	29.23	1.94	0.02
Litter cover + Soil pH	3	-11.18	29.29	1.99	0.02

Litter cover + Range temp.	3	-11.19	29.31	2.01	0.02
Litter cover + Litter depth + Mean temp. + Range temp.	5	-8.41	29.32	2.02	0.02
Litter depth + Mean temp. + Range temp.	4	-9.86	29.33	2.03	0.02
Soil pH	2	-12.45	29.34	2.04	0.02
Litter cover + Litter depth	3	-11.22	29.36	2.06	0.02
Litter cover + Mean temp. + Soil pH	4	-9.96	29.52	2.22	0.02
Herb cover + Litter depth + Range temp.	4	-9.99	29.58	2.28	0.02
Litter depth + Mean temp.	3	-11.33	29.59	2.29	0.02
Mean temp.	2	-12.73	29.91	2.61	0.02
Litter depth + Range temp.	3	-11.55	30.03	2.73	0.02
Herb cover + Litter cover + Litter depth + Mean temp.	5	-8.80	30.09	2.80	0.02
Litter depth + Soil pH	3	-11.74	30.40	3.11	0.01
Herb cover + Litter depth + Soil pH	4	-10.42	30.43	3.14	0.01
Herb cover + Litter cover + Mean temp. + Range temp.	5	-9.00	30.50	3.20	0.01
Herb cover + Mean temp. + Range temp.	4	-10.46	30.52	3.22	0.01
Range temp. + Soil pH	3	-11.84	30.60	3.30	0.01
Herb cover + Litter cover + Mean temp. + Soil pH	5	-9.19	30.87	3.57	0.01
Litter cover + Litter depth + Mean temp. + Soil pH	5	-9.19	30.88	3.59	0.01
Herb cover + Soil pH	3	-11.99	30.91	3.61	0.01
Herb cover + Litter cover + Litter depth + Soil pH	5	-9.21	30.92	3.62	0.01
Herb cover + Range temp. + Soil pH	4	-10.67	30.94	3.64	0.01
Herb cover + Litter depth + Mean temp.	4	-10.72	31.03	3.74	0.01
Litter cover + Mean temp. + Range temp. + Soil pH	5	-9.36	31.22	3.93	0.01
Herb cover + Litter depth + Mean temp. + Range temp.	5	-9.40	31.29	3.99	0.01

j) Functional group R2 (D^2 =0.38; VIF=1.19)

Variables	**Par.**	**LL**	**QAICc**	Δ_i	w_i
Litter cover + Mean temp.	3	-32.74	64.67	0.00	0.18
Litter cover	2	-34.41	64.80	0.13	0.17
Mean temp.	2	-35.09	65.95	1.28	0.10
Herb cover + Litter cover + Mean temp.	4	-32.07	66.45	1.78	0.07
Litter cover + Soil pH	3	-34.05	66.88	2.21	0.06
Litter cover + Mean temp. + Soil pH	4	-32.51	67.20	2.52	0.05
Herb cover + Litter cover	3	-34.25	67.21	2.54	0.05
Litter cover + Litter depth + Mean temp.	4	-32.56	67.27	2.60	0.05
Litter cover + Range temp.	3	-34.32	67.33	2.66	0.05
Herb cover + Mean temp.	3	-34.37	67.42	2.75	0.05
Litter cover + Litter depth	3	-34.41	67.48	2.81	0.04
Litter cover + Mean temp. + Range temp.	4	-32.73	67.56	2.89	0.04
Mean temp. + Soil pH	3	-34.90	68.30	3.63	0.03
Mean temp. + Range temp.	3	-34.97	68.44	3.76	0.03
Litter depth + Mean temp.	3	-35.08	68.62	3.94	0.03

k) Functional group R3 (D^2 =0.25; VIF=1.83)

Variables	**Par.**	**LL**	**QAICc**	Δ_i	w_i
Litter cover	2	-36.04	46.33	0.00	0.34
Litter cover + Mean temp.	3	-35.86	48.81	2.48	0.10
Litter cover + Range temp.	3	-35.90	48.86	2.53	0.10
Herb cover + Litter cover	3	-35.96	48.92	2.59	0.09

Litter cover + Litter depth	3	-36.00	48.97	2.64	0.09
Litter cover + Soil pH	3	-36.03	49.00	2.67	0.09
Range temp.	2	-38.83	49.38	3.05	0.07
Null	1	-41.60	49.93	3.60	0.06
Litter depth	2	-39.35	49.96	3.62	0.06

l) Functional group R4 (D^2=0.18; VIF=1.05)

Variables	**Par.**	**LL**	**QAICc**	Δ_i	w_i
Range temp.	2	-24.30	53.26	0.00	0.16
Mean temp.	2	-24.42	53.50	0.24	0.14
Null	1	-25.95	53.93	0.67	0.11
Mean temp. + Range temp.	3	-23.88	55.13	1.87	0.06
Litter depth + Range temp.	3	-23.99	55.34	2.08	0.06
Litter cover	2	-25.50	55.56	2.30	0.05
Mean temp. + Soil pH	3	-24.22	55.79	2.52	0.04
Litter depth + Mean temp.	3	-24.25	55.84	2.58	0.04
Herb cover + Range temp.	3	-24.26	55.86	2.59	0.04
Range temp. + Soil pH	3	-24.29	55.93	2.66	0.04
Litter cover + Range temp.	3	-24.30	55.94	2.67	0.04
Herb cover	2	-25.74	56.01	2.75	0.04
Soil pH	2	-25.75	56.03	2.77	0.04
Herb cover + Mean temp.	3	-24.36	56.06	2.80	0.04
Litter cover + Mean temp.	3	-24.42	56.18	2.91	0.04
Litter depth	2	-25.90	56.32	3.06	0.03
Litter depth + Mean temp. + Range temp.	4	-23.32	56.98	3.72	0.02

Table S3. Multi-model averages (see Table S2 for list of Poisson generalized linear models with $\Delta_i < 4$ contributing to each average model) relating environmental variables to frog species richness, frog abundance, reptile species richness, reptile abundance, and to abundance of functional groups F1, F2, F3, F4, R1, R2, R3, and R4 (see Tables 1 and 4 for functional group composition and descriptions).

Variable [a]	**Parameter estimate (log scale)**	**Unconditional SE**	**p**	**Relative importance** [b]
Frog species richness				
Intercept	1.2883	1.788	0.48	
Litter cover	0.0067	0.004	0.09	0.67
Herb cover	-0.0051	0.004	0.26	0.33
Mean temp.	-0.0965	0.113	0.41	0.22
Range temp.	0.0164	0.026	0.55	0.16
Litter depth	-0.0077	0.054	0.89	0.12
Soil pH	-0.0299	0.123	0.82	0.11
Frog abundance				
Intercept***	15.1130	1.744	<0.001	
Herb cover***	-0.0197	0.003	<0.001	1.00
Mean temp.***	-0.6739	0.067	<0.001	1.00
Soil pH***	0.6205	0.082	<0.001	1.00
Litter cover*	0.0045	0.002	0.02	0.19
Litter depth	0.0320	0.024	0.21	0.13
Range temp.	-0.0210	0.016	0.22	0.13
Reptile species richness				
Intercept	0.5251	0.983	0.61	
Litter cover	-0.0030	0.004	0.46	0.17
Litter depth	0.0250	0.065	0.71	0.15
Range temp.	0.0145	0.027	0.61	0.11
Herb cover	-0.0015	0.005	0.76	0.10
Soil pH	0.0474	0.167	0.79	0.10
Mean temp.	-0.0083	0.113	0.94	0.10
Reptile abundance				
Intercept	0.7376	1.001	0.48	
Range temp.	0.0214	0.024	0.40	0.16
Soil pH	0.1129	0.157	0.49	0.15
Litter cover	-0.0022	0.003	0.50	0.11
Herb cover	-0.0029	0.004	0.51	0.11
Mean temp.	-0.0294	0.100	0.78	0.10
Litter depth	-0.0068	0.052	0.90	0.09
Functional group F1				

Intercept	6.0830	7.330	0.41	
Herb cover**	-0.0336	0.012	0.01	0.98
Mean temp.*	-0.4645	0.224	0.05	0.55
Soil pH	0.4299	0.243	0.09	0.39
Litter cover	-0.0102	0.006	0.10	0.32
Range temp.	0.0297	0.060	0.63	0.16
Litter depth	0.0044	0.103	0.97	0.13
Functional group F2				
Intercept*	9.7936	3.835	0.01	
Mean temp.***	-0.7106	0.136	<0.001	1.00
Soil pH***	1.1252	0.194	<0.001	1.00
Litter cover***	0.0216	0.006	<0.001	0.76
Herb cover***	-0.0147	0.004	<0.001	0.46
Range temp.	-0.0633	0.055	0.26	0.21
Litter depth	-0.0673	0.050	0.20	0.13
Functional group F3				
Intercept***	13.9233	2.229	<0.001	
Herb cover***	-0.0233	0.004	<0.001	1.00
Mean temp.***	-0.5720	0.088	<0.001	1.00
Soil pH***	0.3597	0.096	<0.001	1.00
Litter cover	0.0008	0.002	0.75	0.13
Litter depth	-0.0089	0.036	0.81	0.13
Range temp.	0.0036	0.022	0.87	0.13
Functional group F4				
Intercept	-6.4449	8.053	0.44	
Litter depth*	0.3902	0.189	0.05	0.83
Litter cover	0.0592	0.093	0.54	0.34
Soil pH	0.8544	0.837	0.33	0.31
Range temp.	-0.0959	0.131	0.48	0.20
Herb cover	0.0062	0.013	0.66	0.13
Mean temp.	-0.0864	0.437	0.85	0.09
Functional group R1				
Intercept	-18.8485	30.801	0.55	
Litter cover	0.1255	0.179	0.50	0.53
Herb cover	-0.0328	0.028	0.27	0.39
Mean temp.	1.1571	1.054	0.29	0.38
Range temp.	-0.2075	0.192	0.30	0.34
Litter depth	0.2913	0.241	0.25	0.34
Soil pH	0.4639	0.759	0.56	0.19
Functional group R2				
Intercept	4.9901	7.682	0.52	
Litter cover	0.0240	0.013	0.08	0.78
Mean temp.*	-0.4551	0.224	0.05	0.63
Herb cover	-0.0079	0.008	0.37	0.17
Soil pH	0.1740	0.246	0.50	0.14
Litter depth	-0.0218	0.095	0.83	0.12

Range temp.	-0.0112	0.048	0.82	0.12
Functional group R3				
Intercept	0.6984	1.755	0.70	
Litter cover**	-0.0161	0.005	<0.01	0.81
Range temp.	0.0545	0.056	0.34	0.17
Litter depth	-0.0954	0.139	0.50	0.15
Mean temp.	-0.0925	0.154	0.57	0.10
Herb cover	0.0026	0.006	0.70	0.09
Soil pH	0.0372	0.258	0.89	0.09
Functional group R4				
Intercept	-4.6615	5.326	0.39	
Range temp.	0.0980	0.063	0.14	0.42
Mean temp.	0.3395	0.226	0.15	0.39
Litter depth	0.0835	0.159	0.61	0.16
Litter cover	-0.0024	0.009	0.79	0.13
Soil pH	-0.1205	0.329	0.73	0.12
Herb cover	0.0004	0.012	0.98	0.12

[a] Significance of each variable in models is indicated by $*p \leq 0.05$, $** p \leq 0.01$, $*** p \leq 0.001$.
[b] Relative importance reflects the sum of Akaike weights of models in each set containing each variable.

SUPPLEMENTARY REFERENCES

Boughton, R.G., Staiger, J. & Franz, R. (2000). Use of PVC pipe refugia as a sampling technique for hylid treefrogs. *Am. Midl. Nat.*, **144:** 168-177.

Buckland, S., *et al.* (2001). *Introduction to Distance Sampling*. Oxford: Oxford University Press.

Clarke, K.R. & Gorley, R.N. (2001). *Change in Marine Communities: An Approach to Statistical Analysis and Interpretation*. Plymouth, United Kingtom: Primer-E.

du Preez, L.H. & Carruthers, V. (2009). *A Complete Guide to Frogs of Southern Africa*. Cape Town: Struik Nature.

Fisher, R., *et al.* (2008). Herpetological monitoring using a pitfall trapping design in Southern California. In *U.S. Geological Survey Techniques and Methods 2-A5*: 44.).

Hilje, B. & Mitchell Aide, T. (2012). Recovery of amphibian species richness and composition in a chronosequence of secondary forests, northeastern Costa Rica. *Biol. Conserv.*, **146:** 170-176.

Kindt, R. & Coe, R. (2005). *Tree Diversity Analysis: A manual and Software for Commom Statistical Methods for Ecological and Biodiversity Studies*. Nairobi: World Agroforestry Centre.

Zuur, A.F., Ieno, E.N., Walker, N.J., Saveliev, A.A. & Smith, G.M. (2009). *Mixed effects models and extensions in ecology with R.* New York: Springer.