

# A before–after assessment of the response of mammals to tourism in a Brazilian national park

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SUPPLEMENTARY TABLE 1 Number of tourists visiting Cavernas do Peruaçu National Park between 2011 and 2017. The Park officially opened for tourism in 2015. Source: ICMBio – Park managers.

	2011	2012	2013	2014	2015	2016	2017
Tourists	260	601	250	622	2,961	3,686	6,865

SUPPLEMENTARY TABLE 2 Details of camera trap sites at Cavernas do Peruaçu National Park.

Site	Latitude (S)	Longitude (W)	Altitude (m)	Vegetation type	Trail category	Nearest site distance (m)	Survey days (before/after tourism)
T1	15° 6'51.35"	44°14'30.20"	618	gallery forest	tourist	716	855 (325/530)
T2	15° 6'26.24"	44°14'14.23"	627	gallery forest	tourist	718	816 (280/536)
T3	15° 5'5.18"	44°15'52.08"	617	gallery forest	tourist	1340	858 (322/536)
T4	15° 6'29.59"	44°14'37.74"	633	dry forest	tourist	716	738 (202/536)
T5	15° 8'51.03"	44°14'6.51"	542	gallery forest	tourist	845	615 (79/536)
NT1	15° 8'6.28"	44°14'37.06"	599	gallery forest	non-tourist	510	823 (286/537)
NT2	15° 6'0.85"	44°13'57.54"	610	gallery forest	non-tourist	754	793 (257/536)
NT3	15° 5'30.26"	44°14'28.97"	634	gallery forest	non-tourist	580	801 (265/536)
NT4	15° 8'26.66"	44°14'19.65"	530	gallery forest	non-tourist	826	858 (322/536)
NT5	15° 5'57.74"	44°14'22.30"	688	dry forest	non-tourist	625	715 (206/509)
NT6	15° 5'40.34"	44°14'12.91"	624	gallery forest	non-tourist	580	705 (169/536)
NT7	15° 5'48.93"	44°15'12.01"	713	dry forest	non-tourist	770	649 (112/537)
NT8	15° 7'57.63"	44°14'51.12"	676	dry forest	non-tourist	510	597 (88/509)
NT9	15° 5'59.78"	44°14'49.32"	723	dry forest	non-tourist	770	617 (81/536)
NT10	15° 7'33.39"	44°14'47.86"	663	dry forest	non-tourist	755	619 (81/538)
NT11	15° 5'22.59"	44°15'11.21"	699	dry forest	non-tourist	1340	617 (81/536)

SUPPLEMENTARY TABLE 3 Native mammal species >1 kg detected at Cavernas do Peruaçu National Park between 2011 and 2017, with conservation status of threatened species. For each species the total number of independent records and the number of independent records and detection rate (records/survey effort  $\times$  100) before and after tourism started in the Park are shown, as well as number of camera trap sites where the species was detected.

Species	24 hours (full dataset)				Core visitation hours (9–17 h)			
	Total records	Before tourism	After tourism	Sites	Total records	Before tourism	After tourism	Sites
Ocelot <i>Leopardus pardalis</i> VU <sup>3</sup>	825	231 (7.32)	594 (6.97)	16	203	87 (2.76)	116 (1.36)	14
Spotted paca <i>Cuniculus paca</i>	613	260 (8.24)	353 (4.14)	10	1	0 (0)	1 (0.01)	1
Rock cavy <i>Kerodon rupestris</i> VU <sup>2</sup>	609	289 (9.16)	320 (3.76)	11	326	168 (5.32)	158 (1.85)	11
Collared peccary <i>Pecari tajacu</i> VU <sup>3</sup>	287	73 (2.31)	214 (2.51)	16	97	30 (0.95)	67 (0.79)	14
Gray brocket deer <i>Mazama gouazoubira</i>	164	64 (2.03)	100 (1.17)	14	59	28 (0.89)	31 (0.36)	13
Coati <i>Nasua nasua</i>	132	92 (2.92)	40 (0.47)	12	84	67 (2.12)	17 (0.20)	12
Tapeti <i>Sylvilagus brasiliensis</i>	128	50 (1.58)	78 (0.92)	6	0	0 (0)	0 (0)	0
Collared anteater <i>Tamandua tetradactyla</i>	76	37 (1.17)	39 (0.46)	14	2	1 (0.03)	1 (0.01)	2
Puma <i>Puma concolor</i> VU <sup>2,3</sup>	63	7 (0.22)	56 (0.66)	12	10	2 (0.06)	8 (0.09)	5
Crab-eating fox <i>Cerdocyon thous</i>	61	3 (0.10)	58 (0.68)	9	0	0 (0)	0 (0)	0
Brazilian porcupine <i>Coendou prehensilis</i>	47	13 (0.41)	34 (0.40)	5	0	0 (0)	0 (0)	0
Giant anteater <i>Myrmecophaga tridactyla</i> VU <sup>1,2,3</sup>	46	18 (0.57)	28 (0.33)	9	5	2 (0.06)	3 (0.03)	5
Crab-eating raccoon <i>Procyon cancrivorus</i>	42	11 (0.35)	31 (0.36)	12	0	0 (0)	0 (0)	0
Nine-banded armadillo <i>Dasypus novemcinctus</i>	30	8 (0.25)	22 (0.26)	10	1	0 (0)	1 (0.01)	1
Tayra <i>Eira barbara</i>	20	8 (0.25)	12 (0.14)	12	10	6 (0.19)	4 (0.05)	6
Striped hog-nosed skunk <i>Conepatus semistriatus</i>	20	9 (0.29)	11 (0.13)	9	0	0 (0)	0 (0)	0

Jaguarundi									
<i>Puma yagouaroundi</i>			15						
VU <sup>2</sup>	19	4 (0.13)	(0.18)	8	7	1 (0.03)	6 (0.07)	5	
Yellow armadillo									
<i>Euphractus sexcinctus</i>	16	9 (0.29)	7 (0.08)	4	4	0 (0)	4 (0.05)	3	
Southern naked-tailed armadillo									
<i>Cabassous unicinctus</i>	9	1 (0.03)	8 (0.09)	4	0	0 (0)	0 (0)	0	
Agouti									
<i>Dasyprocta azarae</i>	6	4 (0.13)	2 (0.02)	3	1	1 (0.03)	0 (0)	1	
Oncilla									
<i>Leopardus tigrinus</i> EN <sup>2</sup>									
VU <sup>1,3</sup>	3	0 (0.00)	3 (0.04)	2	0	0 (0)	0 (0)	0	
Neotropical otter									
<i>Lontra longicaudis</i> VU <sup>3</sup>	3	2 (0.06)	1 (0.01)	2	0	0 (0)	0 (0)	0	
Lesser grison									
<i>Galictis cuja</i>	1	1 (0.03)	0 (0.00)	1	0	0 (0)	0 (0)	0	

EN = Endangered, VU = Vulnerable.

<sup>1</sup> Global status – The IUCN red list of threatened species (2020). IUCN Global Species Programme Red List Unit. [iucnredlist.org](http://iucnredlist.org)

<sup>2</sup> National status – National Red List of Threatened Species from Brazilian Fauna – ICMBio (2018). Livro Vermelho da Fauna Brasileira Ameaçada de Extinção: Volume II – Mamíferos. ICMBio, Brasília, Brazil.

<sup>3</sup> Regional status – Red List of Threatened Species from Minas Gerais State Fauna – COPAM (2010) Lista de espécies ameaçadas de extinção da fauna do estado de Minas Gerais – DN COPAM 147. Belo Horizonte, Brazil.

SUPPLEMENTARY TABLE 4 Variables included in the generalized linear mixed models to estimate species' probability of trail use.

Type of variable	Code	Description	Values
Environmental	Ssn	Season	dry; wet
Environmental	Veg	Vegetation type	gallery forest; dry forest
Tourism	Use	Trail category according to tourist use	tourist; non- tourist
Tourism	Vst	Classification of survey period according to visitation status; official start of tourism in 2015 when number of visitors had a large increase	before; after
Random	Site	Each individual camera trap site	16 distinct categorical values

SUPPLEMENTARY TABLE 5 Ranking and coefficients of generalized linear mixed models used to estimate probability of trail use for six mammal species at Cavernas do Peruaçu National Park (full dataset: 24 h).

<b>Paca</b>									
(Int)	Ssn	Veg	Vst	Use	Vst × Use	df	AICc	ΔAICc	weight
-2.62	-0.25	-4.98	-0.45	0.40	-0.03	7	3,854.50	0.00	0.94
-2.78		-4.99	-0.45	0.40	-0.03	6	3,860.00	5.49	0.06
-5.41	-0.25		-0.45	2.19	-0.02	6	3,870.50	16.02	0.00
-5.58			-0.46	2.19	-0.03	5	3,876.00	21.56	0.00
<b>Rock cavy</b>									
(Int)	Ssn	Veg	Vst	Use	Vst × Use	df	AICc	ΔAICc	weight
-5.08			-0.57	0.51	-1.55	5	3,176.60	0.00	0.45
-4.31		-1.57	-0.57	0.03	-1.55	6	3,177.70	1.06	0.27
-5.11	0.03		-0.56	0.51	-1.55	6	3,178.50	1.89	0.18
-4.33	0.03	-1.57	-0.56	0.04	-1.56	7	3,179.60	2.96	0.10
<b>Ocelot</b>									
(Int)	Ssn	Veg	Vst	Use	Vst × Use	df	AICc	ΔAICc	weight
-2.36	-0.99		-0.38	0.25	0.68	6	5,178.60	0.00	0.73
-2.42	-0.99	0.12	-0.38	0.29	0.68	7	5,180.50	1.96	0.27
-3.03			-0.30	0.28	0.63	5	5,337.40	158.82	0.00
-3.06		0.05	-0.30	0.30	0.63	6	5,339.40	160.81	0.00
<b>Pecari</b>									
(Int)	Ssn	Veg	Vst	Use	Vst × Use	df	AICc	ΔAICc	weight
-3.69	-0.26		-0.14	-0.22	0.61	6	2,604.10	0.00	0.48
-3.84	-0.26	0.31	-0.15	-0.13	0.62	7	2,605.50	1.35	0.25
-3.87			-0.13	-0.21	0.60	5	2,606.10	1.95	0.18
-4.02		0.29	-0.14	-0.12	0.61	6	2,607.50	3.35	0.09
<b>Deer</b>									
(Int)	Ssn	Veg	Vst	Use	Vst × Use	df	AICc	ΔAICc	weight
-4.83	-0.67	2.30	-1.90	0.39	2.29	7	1,534.30	0.00	1.00
-5.28		2.21	-1.79	0.41	2.20	6	1,547.70	13.36	0.00
-3.66	-0.65		-1.87	-0.37	2.28	6	1,549.30	14.94	0.00
-4.12			-1.77	-0.32	2.20	5	1,561.70	27.39	0.00
<b>Coati</b>									
(Int)	Ssn	Veg	Vst	Use	Vst × Use	df	AICc	ΔAICc	weight
-2.95	-2.12	-1.32	-2.28	-0.36	1.77	7	1,075.90	0.00	0.60
-3.55	-2.13		-2.31	-0.05	1.79	6	1,076.70	0.79	0.40
-3.94		-1.56	-2.24	-0.35	1.78	6	1,195.90	119.99	0.00
-4.69			-2.25	0.04	1.80	5	1,197.90	121.98	0.00

Models ranked according to AICc values. Variable code and reference category: Ssn = season (reference category: dry season), Veg = vegetation type (reference category: gallery forest);

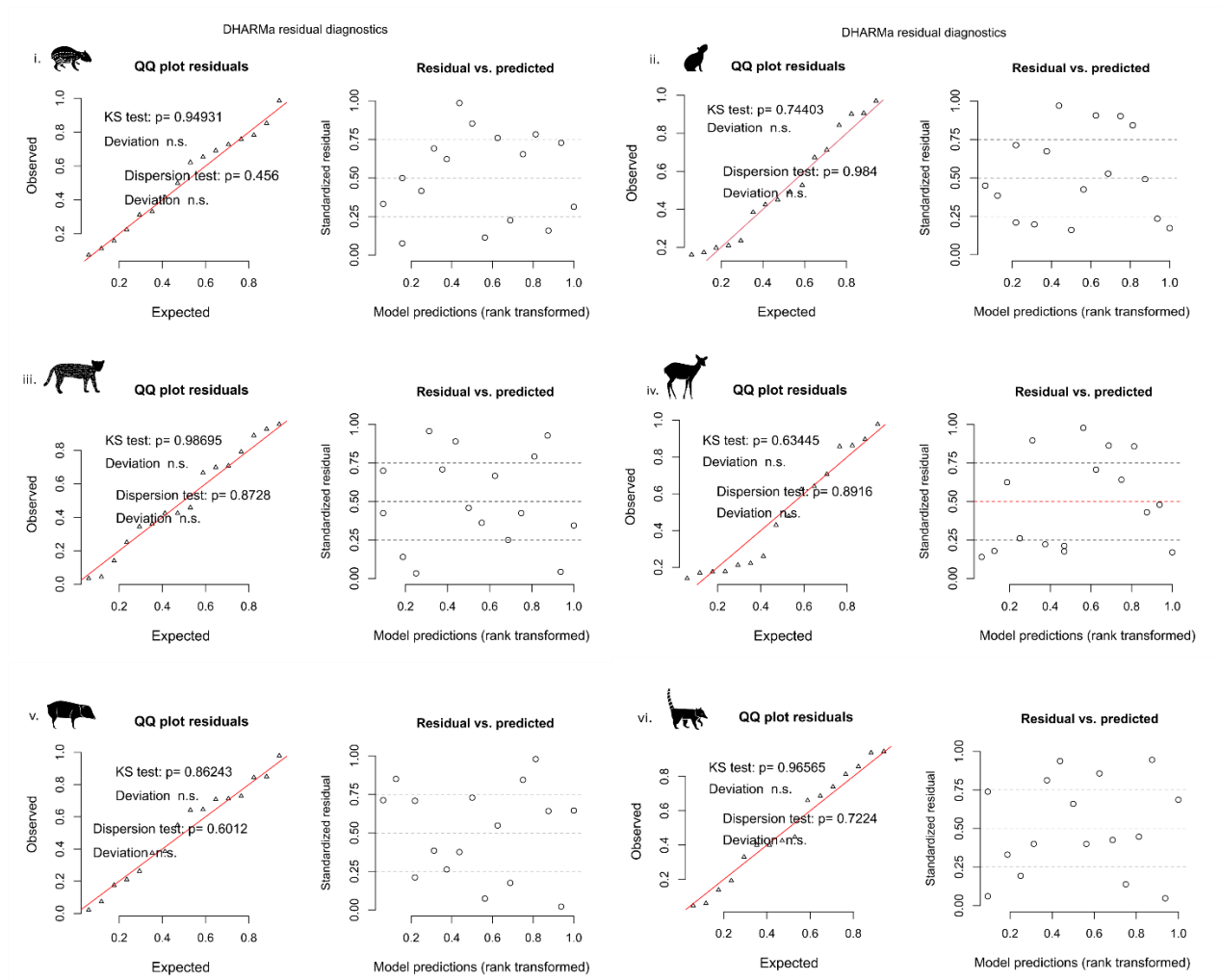
Vst = survey period according to visitation status – before or after tourism (reference category: before tourism), Use = trail category according to tourist use (reference category: non-tourist trail); Vst  $\times$  Use = interaction term between survey period according to visitation status and trail category (reference category: before tourism  $\times$  non-tourist trail). Tourism-related variables were fixed in all models.

SUPPLEMENTARY TABLE 6 Ranking and coefficients of generalized linear mixed models used to estimate probability of trail use for six mammal species at Cavernas do Peruacu National Park during the core visitation hours (09.00–17.00).

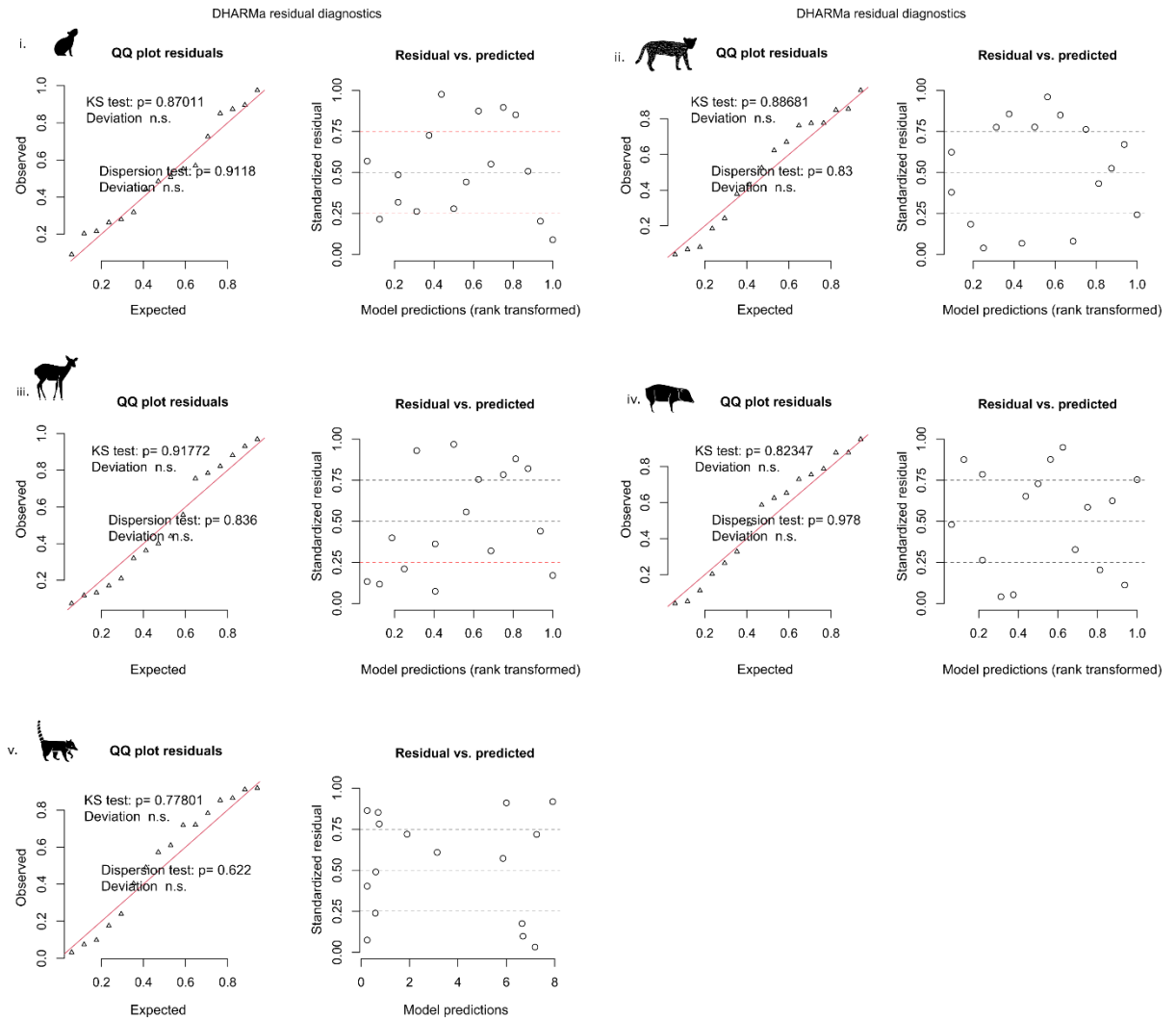
<b>Rock cavy</b>									
(Int)	Ssn	Veg	Vst	Use	Vst × Use	df	AICc	ΔAICc	weight
-5.52	0.41		-0.84	0.38	-0.82	6	2,222.80	0.00	0.54
-4.64	0.41	-1.74	-0.84	-0.16	-0.82	7	2,223.20	0.46	0.43
-5.29			-0.86	0.35	-0.76	5	2,229.80	7.04	0.02
-4.33		-1.71	-0.86	-0.18	-0.77	6	2,230.30	7.55	0.01
<b>Ocelot</b>									
(Int)	Ssn	Veg	Vst	Use	Vst × Use	df	AICc	ΔAICc	weight
-3.34	-1.16		-0.84	-0.22	0.31	6	1,851.10	0.00	0.71
-3.18	-1.15	-0.32	-0.83	-0.31	0.30	7	1,852.80	1.74	0.30
-4.08			-0.76	-0.16	0.24	5	1,911.40	60.38	0.00
-3.86		-0.42	-0.75	-0.27	0.23	6	1,913.00	61.95	0.00
<b>Pecari</b>									
(Int)	Ssn	Veg	Vst	Use	Vst × Use	df	AICc	ΔAICc	weight
-4.87			-0.21	-0.12	0.11	5	1,111.20	0.00	0.53
-4.83	-0.05		-0.21	-0.12	0.11	6	1,113.10	1.95	0.20
-4.88		0.03	-0.21	-0.11	0.11	6	1,113.20	2.00	0.20
-4.84	-0.05	0.03	-0.21	-0.11	0.11	7	1,115.10	3.95	0.07
<b>Deer</b>									
(Int)	Ssn	Veg	Vst	Use	Vst × Use	df	AIC	ΔAIC	weight
-4.77	-0.57	1.15	-2.14	-0.04	2.19	7	705.60	0.00	0.75
-5.14		1.08	-2.08	-0.04	2.15	6	707.80	2.26	0.24
-4.37	-0.52		-2.03	-0.31	2.15	6	714.30	8.69	0.01
-4.71			-1.97	-0.31	2.10	5	715.80	10.20	0.01
<b>Coati</b>									
(Int)	Ssn	Veg	Vst	Use	Vst × Use	df	AICc	ΔAICc	weight
-2.93	-2.43	-1.57	-2.51	-0.23	0.90	7	735.50	0.00	0.78
-3.58	-2.46		-2.59	0.15	0.96	6	738.00	2.54	0.22
-3.94		-1.89	-2.46	-0.29	0.93	6	830.10	94.63	0.00
-4.83			-2.50	0.24	0.97	5	835.00	99.57	0.00

Models ranked according to AICc values. See Supplementary Table 5 for variable codes and reference categories. Tourism-related variables were fixed in all models.



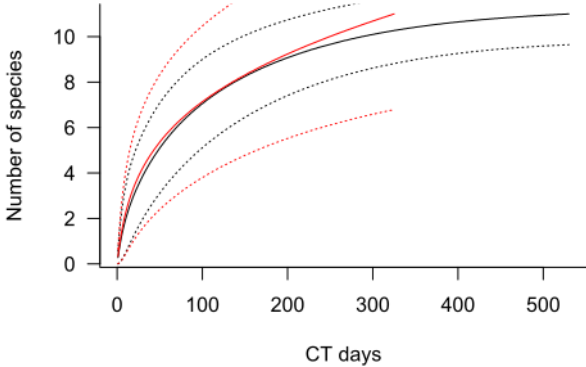
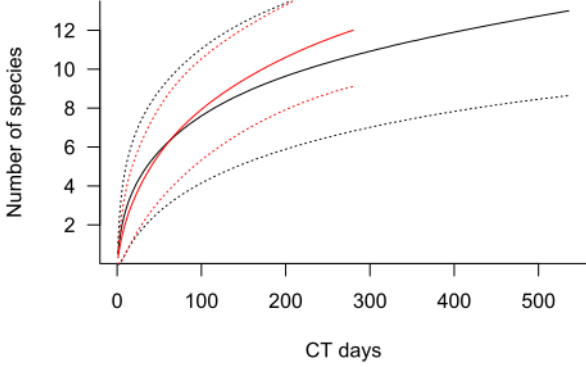


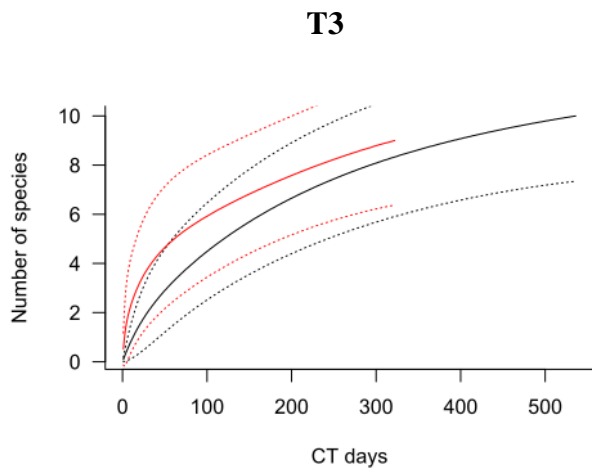
SUPPLEMENTARY FIG. 1 Residual diagnostics plots of global generalized linear mixed models fitted for the six species of mammals assessed (full dataset: 24 h). Assessment based on 1,000 datasets simulated from the fitted model and residuals calculated by comparing the observed data to the new data and grouping according to random factor. Left panels: QQ plots (quantile-quantile plot for a uniform distribution) displaying overall deviation from the expected distribution and results of tests for distribution (Kolmogorov–Smirnov - KS test) and dispersion. Right panels: standard residuals against predicted values. Species: (i) paca *Cuniculus paca*, (ii) rock cavy *Kerodon rupestris*, (iii) ocelot *Leopardus pardalis*, (iv) deer *Mazama gouazoubira*, (v) collared peccary *Pecari tajacu*, (vi) coati *Nasua nasua*.



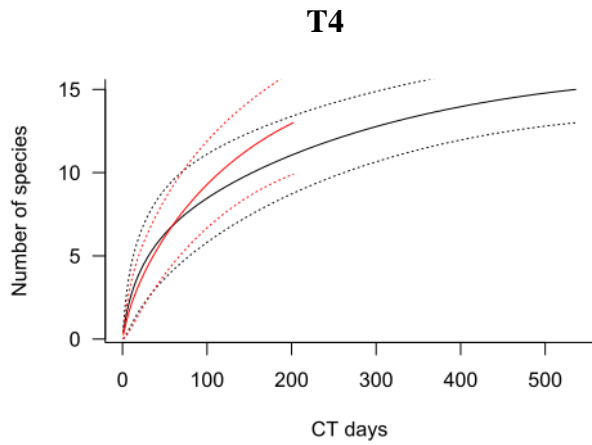
SUPPLEMENTARY FIG. 2 Residual diagnostics plots of global generalized linear mixed models for the core visitation hours (09.00–17.00) fitted for the six species of mammals assessed. Assessment based on 1,000 datasets simulated from the fitted model and residuals calculated by comparing the observed data to the new data and grouping according to random factor. Left panels: QQ plots displaying overall deviation from the expected distribution and results of tests for distribution (KS test) and dispersion. Right panels: standard residuals against predicted values. Species: (i) rock cavy *Kerodon rupestris*, (ii) ocelot *Leopardus pardalis*, (iii) deer *Mazama gouazoubira*, (iv) collared peccary *Pecari tajacu*, (v) coati *Nasua nasua*. Paca *Cuniculus paca* had only a few records in the core visitation hours.

SUPPLEMENTARY TABLE 7 Sample-based rarefaction curves for both before (red) and after (black) tourism in each camera trap site and estimated species richness for the two periods (before and after tourism). Species richness comparisons were made at the value of the lowest camera trap (CT) sampling effort (CT × days) for the pair of sites. Dotted lines indicate the 95% CI of the rarefaction curves.

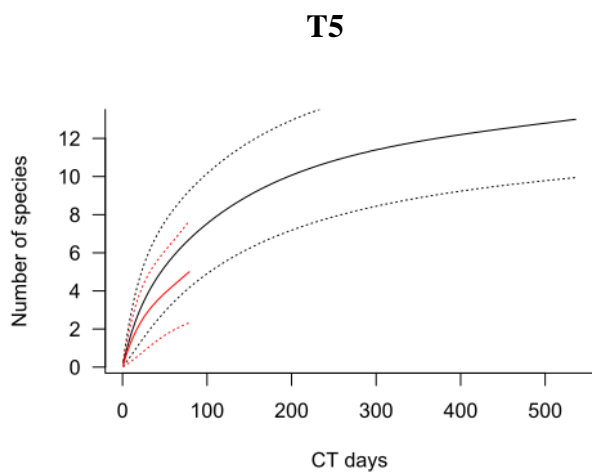
CT site	Observed richness (95% CI range)	Jackknife (95% CI range)	Effort (CT × days)
<p style="text-align: center;"><b>T1</b></p> 	<p style="text-align: center;"><b>Before</b></p> <p style="text-align: center;"><b>11</b></p> <p style="text-align: center;">6.79–15.21</p> <p style="text-align: center;"><b>After</b></p> <p style="text-align: center;"><b>10</b></p> <p style="text-align: center;">8.82–11.72</p>	<p style="text-align: center;"><b>Before</b></p> <p style="text-align: center;"><b>15</b></p> <p style="text-align: center;">10.53–19.45</p> <p style="text-align: center;"><b>After</b></p> <p style="text-align: center;"><b>12</b></p> <p style="text-align: center;">9.23–15.31</p>	325
<p style="text-align: center;"><b>T2</b></p> 	<p style="text-align: center;"><b>Before</b></p> <p style="text-align: center;"><b>12</b></p> <p style="text-align: center;">9.11–14.89</p> <p style="text-align: center;"><b>After</b></p> <p style="text-align: center;"><b>11</b></p> <p style="text-align: center;">6.82–14.57</p>	<p style="text-align: center;"><b>Before</b></p> <p style="text-align: center;"><b>16</b></p> <p style="text-align: center;">11.53–20.45</p> <p style="text-align: center;"><b>After</b></p> <p style="text-align: center;"><b>14</b></p> <p style="text-align: center;">10.16–18.04</p>	280



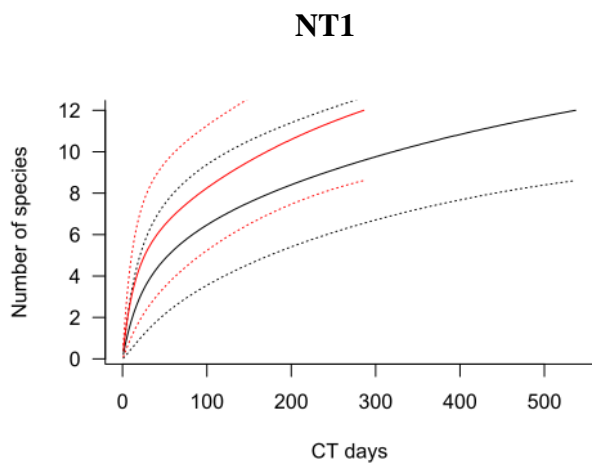
<b>Before</b>	<b>Before</b>	322
<b>9</b>	<b>12</b>	
6.37–11.63	8.12–15.86	
<b>After</b>	<b>After</b>	
<b>8</b>	<b>11</b>	
5.91–10.76	7.57–15.41	



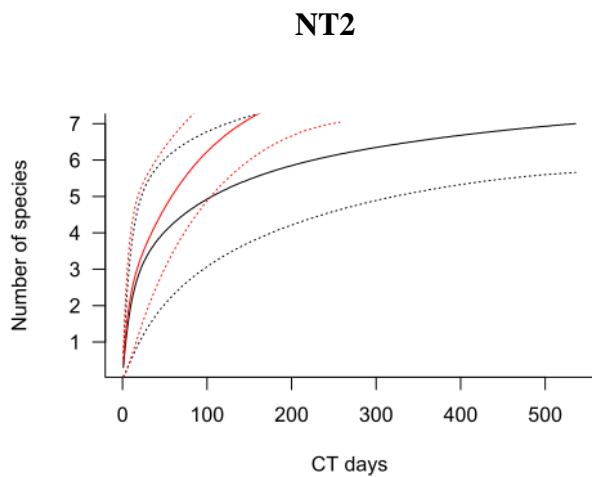
<b>Before</b>	<b>Before</b>	202
<b>13</b>	<b>18</b>	
9.9–16.1	13.01–22.95	
<b>After</b>	<b>After</b>	
<b>11</b>	<b>15</b>	
8.77–13.42	10.71–19.39	



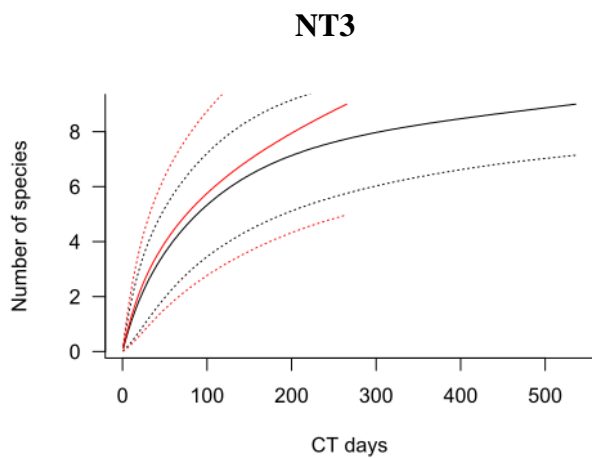
<b>Before</b>	<b>Before</b>	79
<b>5</b>	<b>8</b>	
2.33–7.67	4.10–11.82	
<b>After</b>	<b>After</b>	
<b>7</b>	<b>10</b>	
4.17–9.25	5.90–14.26	



<b>Before</b>	<b>Before</b>	
<b>12</b>	<b>16</b>	
8.61–15.39	11.53–20.45	
<b>After</b>	<b>After</b>	286
<b>10</b>	<b>13</b>	
6.55–12.63	9.15–17.57	



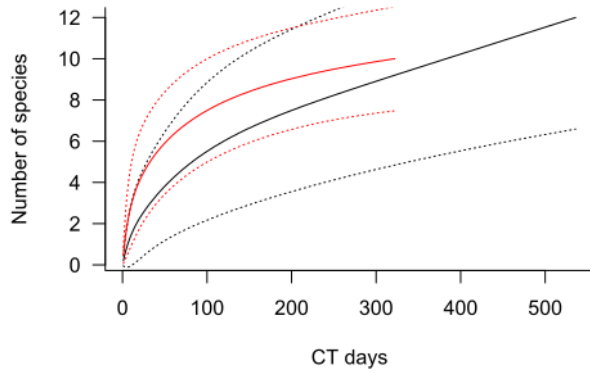
<b>Before</b>	<b>Before</b>	
<b>8</b>	<b>9</b>	
7.04–8.96	6.75–11.25	
<b>After</b>	<b>After</b>	257
<b>6</b>	<b>7</b>	
4.64–7.69	5.28–9.34	



<b>Before</b>	<b>Before</b>	
<b>9</b>	<b>13</b>	
4.97–13.03	8.52–17.44	
<b>After</b>	<b>After</b>	265
<b>8</b>	<b>9</b>	
5.76–9.71	6.58–12.40	

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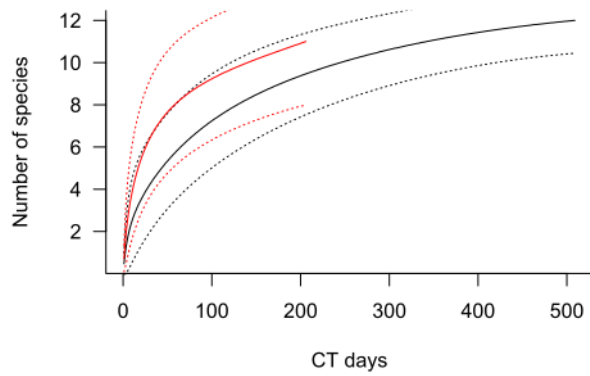
### NT4



<b>Before</b>	<b>Before</b>	322
<b>10</b>	<b>12</b>	
7.47–12.53	8.81–15.17	
<b>After</b>	<b>After</b>	
<b>9</b>	<b>14</b>	
4.84–13.56	8.93–18.07	

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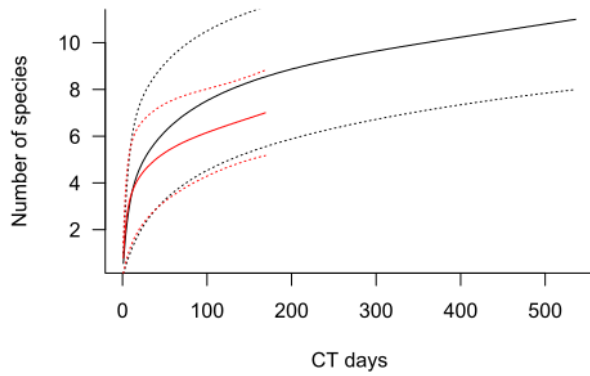
### NT5



<b>Before</b>	<b>Before</b>	206
<b>11</b>	<b>14</b>	
8–14	10.11–17.87	
<b>After</b>	<b>After</b>	
<b>9</b>	<b>13</b>	
7.53–11.4	8.79–16.33	

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### NT6

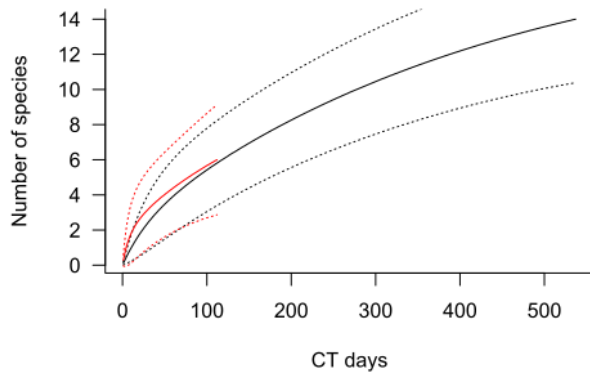


<b>Before</b>	<b>Before</b>	169
<b>7</b>	<b>9</b>	
5.17–8.83	5.82–12.16	
<b>After</b>	<b>After</b>	
<b>9</b>	<b>10</b>	
5.55–11.54	7.50–12.92	

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### NT7



**Before**

**6**

2.87–9.13

**After**

**6**

3.39–8.23

**Before**

**9**

5.11–12.83

**After**

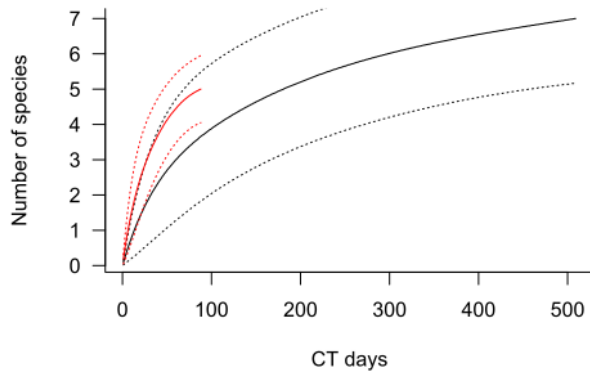
**9**

5.34–13.56

112

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### NT8



**Before**

**5**

4.05–5.95

**After**

**4**

1.83–5.48

**Before**

**6**

3.73–8.25

**After**

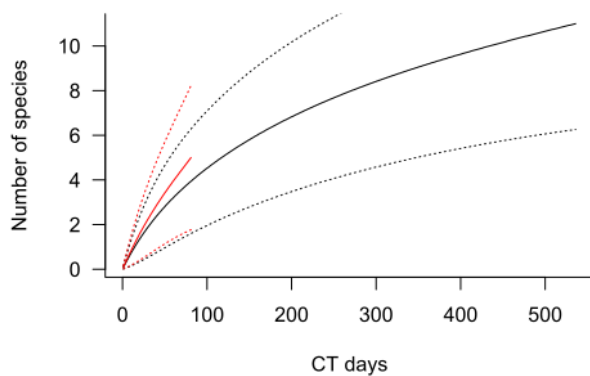
**6**

2.65–8.35

88

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### NT9



**Before**

**5**

1.77–8.23

**After**

**4**

1.6–6.28

**Before**

**9**

4.52–13.38

**After**

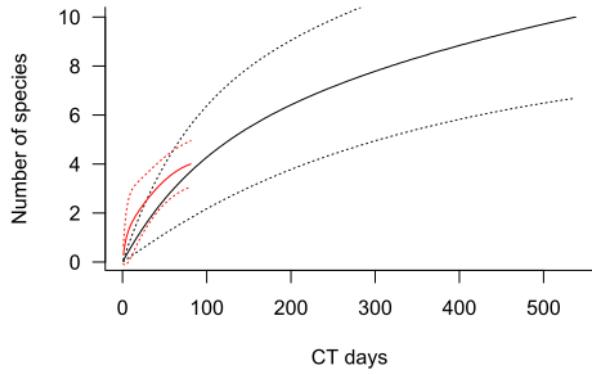
**7**

3.0–10.44

81

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### NT10



**Before**

**4**

3.05–4.95

**After**

**4**

1.8–5.59

**Before**

**5**

2.73–4.25

**After**

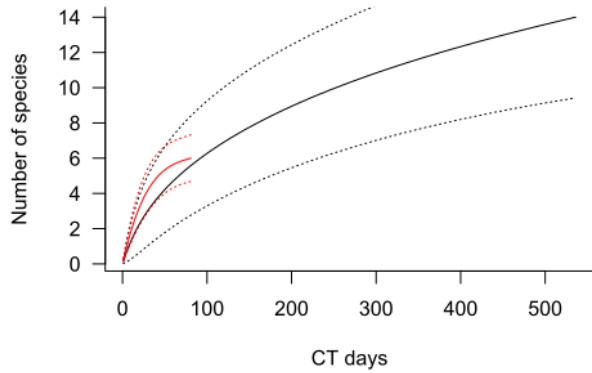
**6**

2.79–10.15

81

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### NT11



**Before**

**6**

4.68–7.32

**After**

**6**

2.77–8.4

**Before**

**7**

4.73–9.25

**After**

**9**

5.22–13.04

81