

Integrative phylogeography reveals conservation priorities for the giant anteater *Myrmecophaga tridactyla* in Brazil

Raphael T. F. Coimbra^{1,2,*}, Rafael F. Magalhães^{3,4}, Priscila Lemes⁵, Flávia R. Miranda^{4,6} and Fabrício R. Santos^{1,4,*}

¹ Programa de Pós-Graduação em Genética, Departamento de Genética, Ecologia e Evolução, Instituto de Ciências Biológicas, Universidade Federal de Minas Gerais, Belo Horizonte 31270-901, MG, Brazil

² Institute for Ecology, Evolution and Diversity, Goethe University, 60439 Frankfurt am Main, Germany

³ Departamento de Ciências Naturais, Campus Dom Bosco, Universidade Federal de São João del-Rei, São João del-Rei 36301-160, MG, Brazil; rafaelfelixm@gmail.com

⁴ Programa de Pós-Graduação em Zoologia, Departamento de Zoologia, Instituto de Ciências Biológicas, Universidade Federal de Minas Gerais, Belo Horizonte 31270-901, MG, Brazil; flavia@tamandua.org

⁵ Laboratório de Ecologia e Biogeografia da Conservação, Departamento de Botânica e Ecologia, Instituto de Biociências, Universidade Federal do Mato Grosso, Cuiabá 78068-600, MT, Brazil; priscila.lemes.azevedo@gmail.com

⁶ Departamento de Ciências Agrárias e Ambientais, Universidade Estadual de Santa Cruz, Ilhéus 45662-900, BA, Brazil

* Correspondence: raphael.t.f.coimbra@gmail.com (R.T.F.C.); fabricio-santos@ufmg.br (F.R.S.)

Figure S1. Dated phylogenetic tree of Cytb haplotypes.

Figure S2. Plot of probability densities for each number of clusters assessed in Geneland.

Figure S3. Time-scaled extended Bayesian skyline plot for the CEPTAF cluster.

Figure S4. Maps of variance component (relative sum of squares) for the CEPTAF cluster.

Table S1. List of samples and sampling localities.

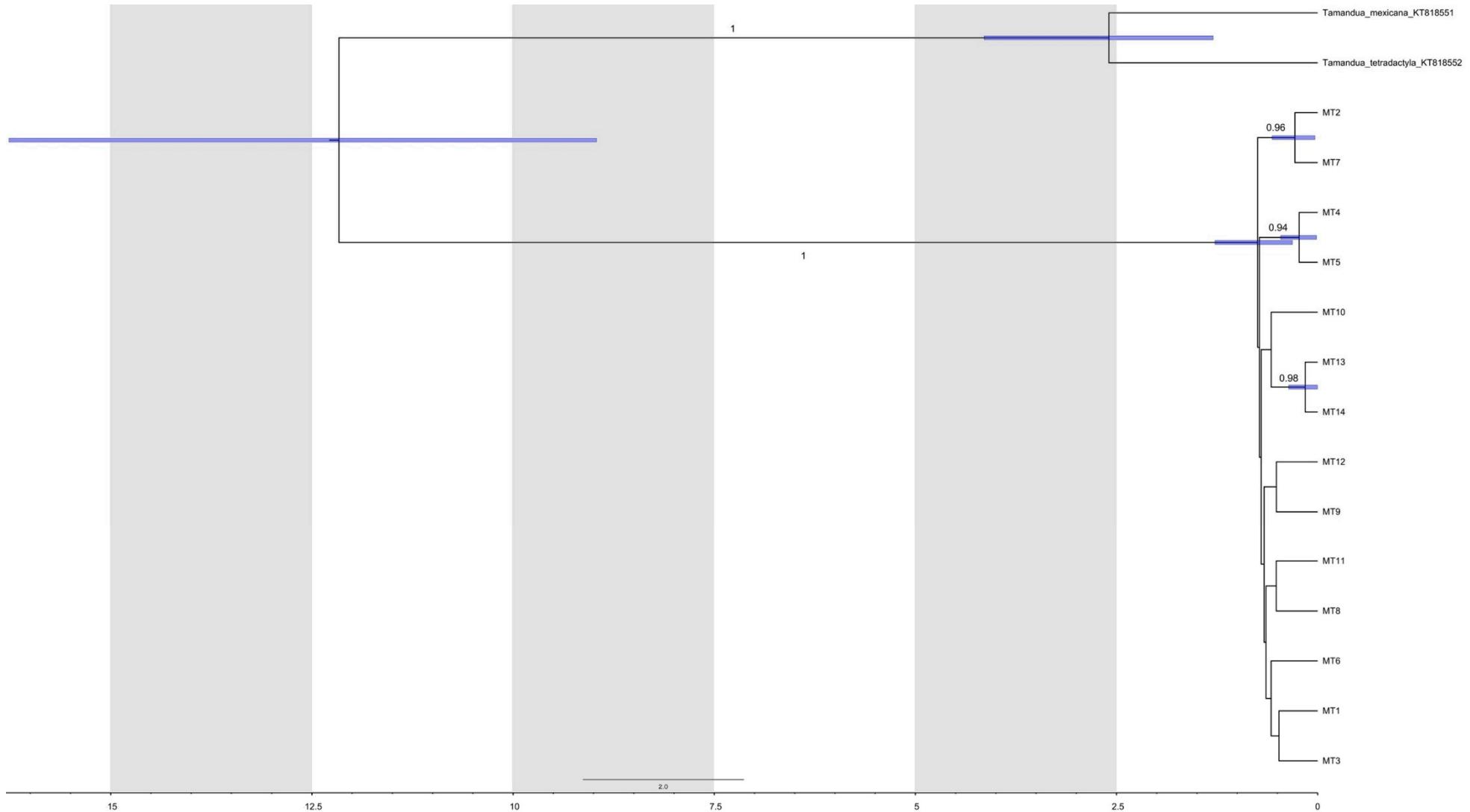
Table S2. List of primers used for each marker and their references.

Table S3. Summary of parameter estimates for each model tested in Migrate-n.

Table S4. AUC values for ecological niche models and general circulation models used to perform the ensemble forecasting for the CEPTAF cluster.

Table S5. Methodological uncertainties of the modelling components from the ecological niche modelling predictions for the CEPTAF cluster.

Table S6. Ecological niche models and general circulation models used to perform the ensemble forecasting for the AM cluster.



Cytb haplotypes: samples

MT1: MPEG01652, M1683, Filhote, TBC02, TBC03, TBC06, TBC08, TBC09, TBC10, TBC12, TBC16, TBC17, TBC20, TBC21, TBC22, TBC23, TBC24, TBC25, TBC26, TBC28, TBC29, TBC30, TBC31, M0668, M2004, M0985, M2008, M0986, M0707, M1776, M2146, TBR, M0663, M0712, SCMT01, SCMT02, SCMT04, SCMT05, SCMT06, SCMT07, SCMT09, SCMT10, SCMT12, SCMT13, SCMT15, FRM05, LabBMC0135, LabBMC0083, LabBMC0155, LabBMC0397, LabBMC0168, LabBMC0007, LabBMC0136, LabBMC0144, LabBMC0121, LabBMC0122, M1676, FRM03, FRM06, M0682, M0980, M0883, MTTA02, MTTA04, MTTA10, M0705, MPEG00565, MPEG01246, M2017, M2018, FB01, FB02, M2019, M1677, M0977, M1678, M2023, M0680, M0685, M0686, M0687, M0693, KT818549
MT2: TBC04
MT3: MPEG01662, MPEG08887, MPEG10211, MPEG01741
MT4: LabBMC0124, M0684

MT5: M0681
MT6: M0697
MT7: TBC07, TBC13, TBC15
MT8: M0696
MT9: FRM02, M0698
MT10: SCMT11, TBC11
MT11: SCMT03, TBC01
MT12: SCMT08
MT13: LabBMC0012, LabBMC0110,
MT14: LabBMC0281

Figure S1. Dated phylogenetic tree of Cytb haplotypes. The two *Tamandua* species were used as outgroups. Hard minimum and soft maximum age constraints for the Myrmecophagidae node were based on the 95% CI (7.0–19.8 Ma) from Gibb et al. [69]. Node bars represent the 95% highest posterior density (HPD) intervals for node age. Node ages and branch support are shown for branches with posterior probability ≥ 0.90 .

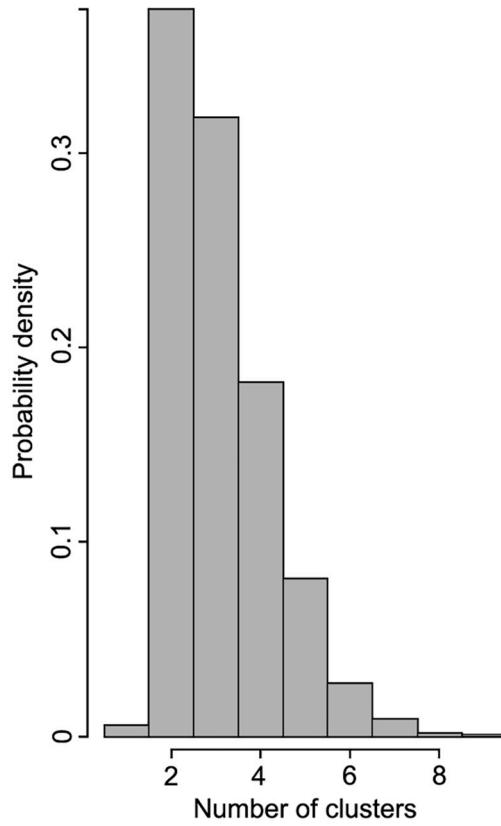


Figure S2. Plot of probability densities for each number of clusters assessed in Geneland.

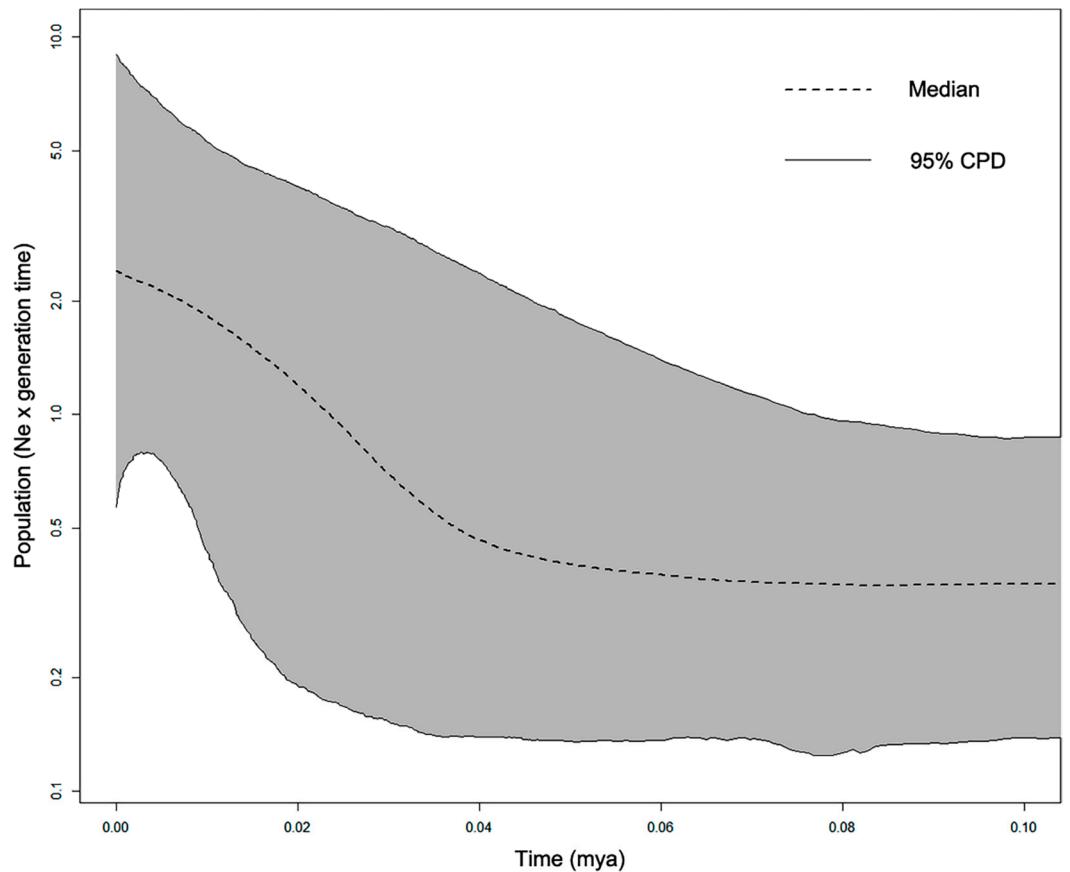


Figure S3. Time-scaled extended Bayesian skyline plot for the CEPTAF cluster. Result is similar to that shown in Fig. 4. The dashed line represents the median estimate and the shaded area around it correspond to the 95% central posterior density (CPD).

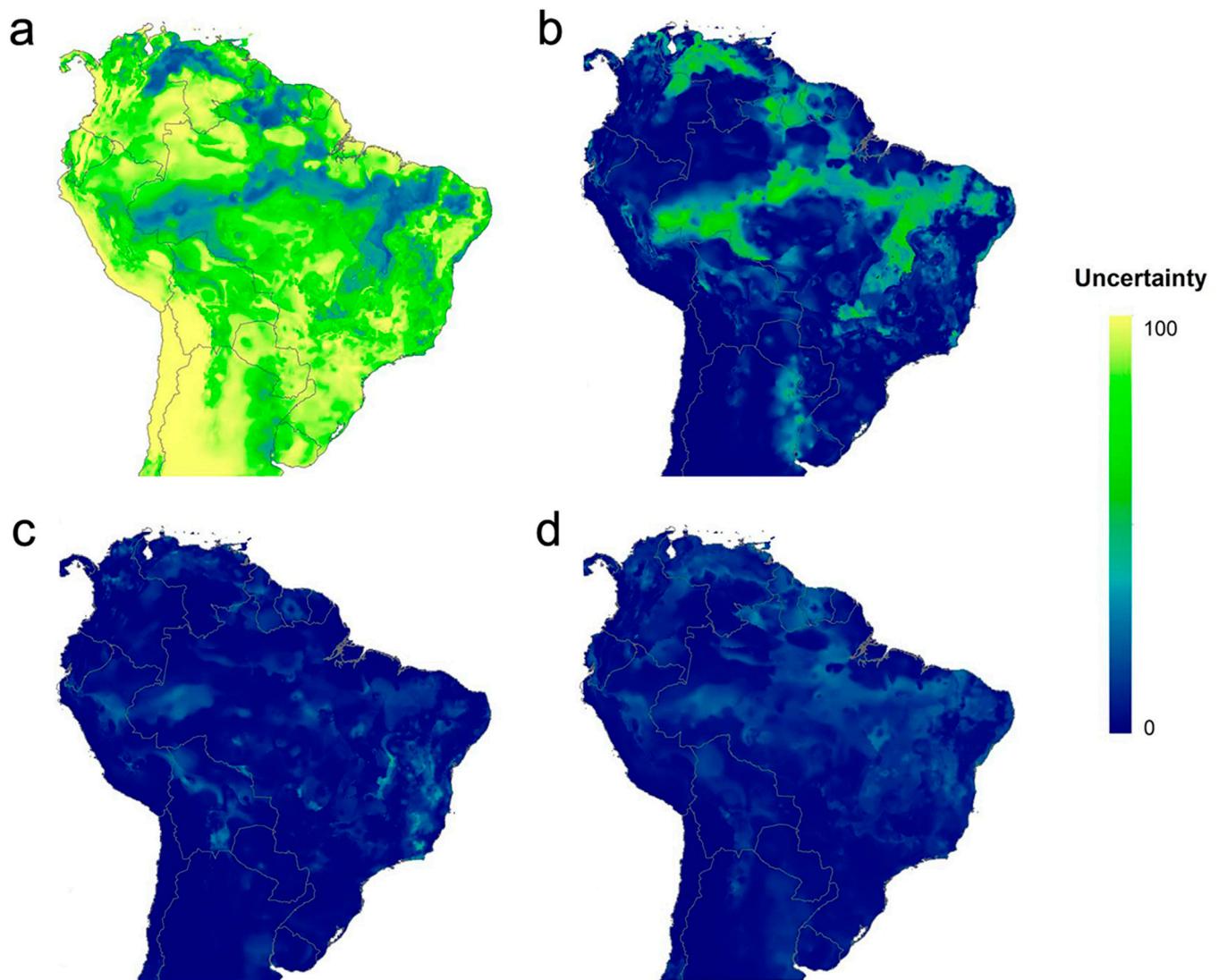


Figure S4. Maps of variance component (relative sum of squares) for the CEPTAF cluster. Effect of (A) ecological niche models (ENMs), (B) general circulation models (GCMs), (C) ENM x GCM interaction, and (D) time.

Table S1. List of samples and sampling localities. Coordinates for localities marked with a * are rough approximations. AM: Amazonia; CE: Cerrado; PT: Pantanal; AF: Atlantic Forest.

Sample ID	Locality	Biome	Longitude	Latitude
MPEG01652	Mazagão, Amapá*	AM	51°43'56.80"W	00°11'02.46"S
MPEG01662	Mazagão, Amapá*	AM	51°43'56.80"W	00°11'02.46"S
M0681	Cristalina, Goiás*	CE	47°31'53.97"W	16°47'40.70"S
M1683	Mineiros, Goiás	CE	52°42'16.92"W	17°36'37.08"S
Filhote	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC01	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC02	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC03	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC04	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC06	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC07	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC08	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC09	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC10	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC11	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC12	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC13	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC15	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC16	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC17	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC20	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC21	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC22	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC23	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC24	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC25	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC26	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC28	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC29	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC30	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
TBC31	Emas NP, Goiás*	CE	52°54'54.32"W	18°07'17.86"S
M0668	Araxá, Minas Gerais*	CE	46°58'05.00"W	19°39'07.31"S
M2004	Bom Despacho, Minas Gerais	CE	45°10'34.30"W	19°47'12.10"S
M0985	Dores do Indaiá, Minas Gerais	CE	45°36'49.70"W	19°31'04.60"S
M2008	Dores do Indaiá, Minas Gerais	CE	45°34'19.70"W	19°26'12.10"S
M0986	Doresópolis, Minas Gerais*	CE	45°52'52.43"W	20°17'35.27"S
M0707	Piumhi, Minas Gerais	CE	45°56'45.00"W	20°27'42.00"S
M1776	Quartel Geral, Minas Gerais	CE	45°38'51.10"W	19°18'36.00"S
M2146	Uberlândia, Minas Gerais*	CE	48°20'03.31"W	19°01'44.18"S
TBR	Uberlândia, Minas Gerais*	CE	48°20'03.31"W	19°01'44.18"S
M0663	Serra da Canastra NP, Minas Gerais*	CE	46°37'21.39"W	20°15'09.69"S
M0712	Serra da Canastra NP, Minas Gerais*	CE	46°37'21.39"W	20°15'09.69"S
SCMT01	Serra da Canastra NP, Minas Gerais*	CE	46°37'21.39"W	20°15'09.69"S
SCMT02	Serra da Canastra NP, Minas Gerais*	CE	46°37'21.39"W	20°15'09.69"S
SCMT03	Serra da Canastra NP, Minas Gerais*	CE	46°37'21.39"W	20°15'09.69"S
SCMT04	Serra da Canastra NP, Minas Gerais*	CE	46°37'21.39"W	20°15'09.69"S
SCMT05	Serra da Canastra NP, Minas Gerais*	CE	46°37'21.39"W	20°15'09.69"S
SCMT06	Serra da Canastra NP, Minas Gerais*	CE	46°37'21.39"W	20°15'09.69"S
SCMT07	Serra da Canastra NP, Minas Gerais*	CE	46°37'21.39"W	20°15'09.69"S
SCMT08	Serra da Canastra NP, Minas Gerais*	CE	46°37'21.39"W	20°15'09.69"S
SCMT09	Serra da Canastra NP, Minas Gerais*	CE	46°37'21.39"W	20°15'09.69"S
SCMT10	Serra da Canastra NP, Minas Gerais*	CE	46°37'21.39"W	20°15'09.69"S

Sample ID	Locality	Biome	Longitude	Latitude
SCMT11	Serra da Canastra NP, Minas Gerais*	CE	46°37'21.39"W	20°15'09.69"S
SCMT12	Serra da Canastra NP, Minas Gerais*	CE	46°37'21.39"W	20°15'09.69"S
SCMT13	Serra da Canastra NP, Minas Gerais*	CE	46°37'21.39"W	20°15'09.69"S
SCMT15	Serra da Canastra NP, Minas Gerais*	CE	46°37'21.39"W	20°15'09.69"S
LabBMC0012	Anastácio, Mato Grosso do Sul	CE	55°36'07.00"W	20°31'15.00"S
FRM05	Aquidauana, Mato Grosso do Sul*	PT	55°49'04.04"W	19°56'02.45"S
LabBMC0135	Bataguassu, Mato Grosso do Sul	CE	52°31'07.00"W	21°47'37.00"S
LabBMC0083	Campo Grande, Mato Grosso do Sul	CE	54°32'01.00"W	20°45'05.00"S
M0697	Corumbá, Mato Grosso do Sul*	PT	56°37'19.00"W	18°59'11.00"S
M0698	Corumbá, Mato Grosso do Sul*	PT	56°37'19.00"W	18°59'11.00"S
LabBMC0110	Miranda, Mato Grosso do Sul	PT	56°51'40.00"W	19°54'44.00"S
LabBMC0124	Miranda, Mato Grosso do Sul	PT	56°14'33.00"W	20°18'43.00"S
LabBMC0155	Nova Alvorada do Sul, Mato Grosso do Sul	CE	54°28'23.00"W	21°10'39.00"S
LabBMC0281	Nova Alvorada do Sul, Mato Grosso do Sul	CE	54°15'49.00"W	21°29'56.00"S
LabBMC0397	Nova Alvorada do Sul, Mato Grosso do Sul	CE	53°51'03.00"W	21°36'02.00"S
LabBMC0168	Nova Andradina, Mato Grosso do Sul	CE	53°16'39.00"W	21°44'52.00"S
LabBMC0007	Ribas do Rio Pardo, Mato Grosso do Sul	CE	53°04'09.00"W	20°26'34.00"S
LabBMC0136	Ribas do Rio Pardo, Mato Grosso do Sul	CE	54°03'51.00"W	20°28'00.00"S
LabBMC0144	Terenos, Mato Grosso do Sul	CE	54°53'56.00"W	20°25'47.00"S
LabBMC0121	Três Lagoas, Mato Grosso do Sul	CE	52°29'44.00"W	20°33'54.00"S
LabBMC0122	Três Lagoas, Mato Grosso do Sul	CE	51°57'17.00"W	20°46'46.00"S
M1676	Água Boa, Mato Grosso*	CE	52°09'30.96"W	14°03'00.00"S
FRM02	Barão de Melgaço, Mato Grosso*	PT	56°16'02.24"W	16°42'17.25"S
FRM03	Barão de Melgaço, Mato Grosso*	PT	56°16'02.24"W	16°42'17.25"S
FRM06	Barão de Melgaço, Mato Grosso*	PT	56°16'02.24"W	16°42'17.25"S
M0682	Barão de Melgaço, Mato Grosso*	PT	56°16'02.24"W	16°42'17.25"S
M0696	Barão de Melgaço, Mato Grosso*	PT	56°16'02.24"W	16°42'17.25"S
M0980	Barão de Melgaço, Mato Grosso*	PT	56°16'02.24"W	16°42'17.25"S
M0883	Nova Xavantina, Mato Grosso*	CE	52°21'11.00"W	14°40'24.00"S
MTTA02	Nova Xavantina, Mato Grosso*	CE	52°21'11.00"W	14°40'24.00"S
MTTA04	Nova Xavantina, Mato Grosso*	CE	52°21'11.00"W	14°40'24.00"S
MTTA10	Nova Xavantina, Mato Grosso*	CE	52°21'11.00"W	14°40'24.00"S
M0705	Vila Rica, Mato Grosso*	AM	51°07'08.65"W	10°00'51.15"S
MPEG08887	Belém, Pará*	AM	48°25'09.38"W	01°25'53.63"S
MPEG00565	Ilha do Marajó, Pará*	AM	49°38'21.50"W	00°56'26.45"S
MPEG01246	Ilha do Marajó, Pará*	AM	49°38'21.50"W	00°56'26.45"S
MPEG10211	Oriximiná, Pará*	AM	57°02'41.93"W	01°04'47.88"S
M2017	Arapoti, Paraná	AF	49°48'35.07"W	24°05'47.15"S
M2018	Arapoti, Paraná	AF	49°49'35.97"W	24°09'02.68"S
FB01	Jaguaraiá, Paraná	AF	49°43'21.44"W	24°14'33.83"S
FB02	Jaguaraiá, Paraná	AF	49°43'21.44"W	24°14'33.83"S
M2019	Jaguaraiá, Paraná	AF	49°40'44.04"W	24°14'31.11"S
M1677	Piraí do Sul, Paraná	AF	49°55'40.25"W	24°32'23.33"S
M0977	Telêmaco Borba, Paraná*	AF	50°33'26.00"W	24°12'42.00"S
M1678	Telêmaco Borba, Paraná	AF	50°33'26.00"W	24°12'42.00"S
MPEG01741	Caracaraí, Roraima*	AM	61°50'42.62"W	01°14'40.33"N
M2023	São Joaquim da Barra, São Paulo*	CE	47°55'45.76"W	20°32'52.86"S
M0680	São José do Rio Preto, São Paulo*	CE	49°20'40.00"W	20°48'49.00"S
M0684	São José do Rio Preto, São Paulo*	CE	49°20'40.00"W	20°48'49.00"S
M0685	São José do Rio Preto, São Paulo*	CE	49°20'40.00"W	20°48'49.00"S
M0686	São José do Rio Preto, São Paulo*	CE	49°20'40.00"W	20°48'49.00"S
M0687	São José do Rio Preto, São Paulo*	CE	49°20'40.00"W	20°48'49.00"S
M0693	São José do Rio Preto, São Paulo*	CE	49°20'40.00"W	20°48'49.00"S
KT818549	French Guiana*	AM	53°04'55.23"W	03°51'37.05"N

Table S2. List of primers used for each marker and their references.

Locus	Primer pairs (5'-3')	Source
HVI	L15445: CCCAAAGCTGAAATTCTACTTAAACTA	Douzery and Randi (1997)
	H15978: ATGACCTGAAGAAAACAACCAG	Huchon et al. (1999)
	ProL: ATTACACTGGTCTTGTAAACC H16498: CCTGAAGTAGGAACCAGATG	LBEM Ward et al. (1991)
Cytb	Cytb-L: CCATGAGGACAAATATCATTCTGAGG Cytb-H: TGGTTTACAAGACCAGTGTAAT	Coimbra et al. (2017)
RAG2	External F220: GATTCCCTGCTAYCTYCCTCCTCT	Teeling et al. (2000)
	R995: CCCATGTTGCTTCCAACCATA	
	Internal TCATGGAGGGAAAACACCAAA TGCAGGACAGAGATTG	Murphy et al. (2001)
VWF	vWF1F: TGTCAACCTCACCTGTGAAGCCTG vWF1R: TGCAGGACCAAGTCAGGAGCCTCTC	Schetino et al. (2017)
BDNF	CATCCTTTCTTACTATGGTT TTCCAGTGCCTTTGTCTATG	Murphy et al. (2001)

Table S3. Summary of parameter estimates for each model tested in Migrate-n. We report the mode and the 95% highest posterior density (HPD) intervals for the mutation-scaled effective immigration rate (M) and mutation-scaled effective population sizes (θ). Numerals I–V correspond to models in Table 1. AM: Amazon cluster; CEPTAF: Cerrado, Pantanal, and Atlantic Forest cluster.

Model	Parameter	Mode	95% HPD
I	θ	0.00327	0.00240–0.00385
	θ_{AM}	0.00059	0.00018–0.00107
II	θ_{CEPTAF}	0.00348	0.00243–0.00389
	$M_{AM \rightarrow CEPTAF}$	1667.2	802.7–2891
	$M_{CEPTAF \rightarrow AM}$	365.2	0–1316
III	θ_{AM}	0.00086	0.00036–0.00147
	θ_{CEPTAF}	0.00345	0.00236–0.00389
	$M_{AM \rightarrow CEPTAF}$	1368.5	616–2692.7
IV	θ_{AM}	0.00071	0.00011–0.00310
	θ_{CEPTAF}	0.00290	0.00212–0.00372
	$M_{CEPTAF \rightarrow AM}$	1030.2	289.3–3073
V	θ_{AM}	0.00001	0–0.00025
	θ_{CEPTAF}	0.00295	0.00216–0.00377

Table S4. AUC values for ecological niche models and general circulation models used to perform the ensemble forecasting for the CEPTAF cluster.

ENMs	Current	LGM		Mid-Holocene		Future	
		CCSM4	MIROC-ESM	CCSM4	MIROC-ESM	CCSM4	MIROC-ESM
Bioclim	0.855	0.905	0.850	0.862	0.883	0.872	0.911
Gower	0.959	0.994	0.944	0.954	0.991	0.967	0.938
SVM	0.987	0.990	0.986	0.995	0.995	0.982	0.995
Maxent	1.00	1.00	0.994	0.996	0.999	0.997	0.994

Table S5. Methodological uncertainties of the modelling components from the ecological niche modelling predictions for the CEPTAF cluster. Median, minimum and maximum of the total sum of squares (SS) of the hierarchical ANOVA.

Source of variation	Median SS	Min SS	Max SS
Time	0.022	0.00	0.479
GCM	0.055	0.00	0.721
ENM	0.843	0.141	0.998
GCM x ENM	0.048	0.00	0.301

Table S6. Ecological niche models and general circulation models used to perform the ensemble forecasting for the AM cluster. Significant values ($p < 0.05$) are in bold.

ENMs	Current	LGM		Mid-Holocene		Future	
		CCSM4	MIROC-ESM	CCSM4	MIROC-ESM	CCSM4	MIROC-ESM
Bioclim	0.169	1.000	0.002	1.000	0.063	1.000	1.000
Gower	0.136	1.000	0.021	0.004	0.153	0.041	1.000
SVM	0.060	0.870	0.894	0.186	0.156	0.193	0.061
Maxent	0.031	0.043	0.077	0.034	0.036	0.079	0.012