

Low Levels of Fruit Nitrogen as Drivers for the Evolution of Madagascar's Primate Communities

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Supplementary Table S1. Nitrogen concentrations of fruits at various sites in the Old World, Madagascar, and the New World. Nitrogen concentrations in fruits have been calculated either by general sampling (GS) or using samples consumed by a specific primate species (PF). Taxonomic source as for Mittermeier et al. 2013 [84].

Site	Country	Mean % Nitrogen concentration in fruits (sample size)	Sampling	Source
Old World				
Campo	Cameroon	1.16 (13)	PF: <i>Gorilla gorilla gorilla</i> , <i>Cercocebus torquatus</i>	1, 2
Lope	Gabon	0.84 (46)	PF: <i>Gorilla gorilla gorilla</i>	3
Bai Hokou	Central African Republic	1.36 (22)	PF: <i>Gorilla gorilla gorilla</i>	4
Bwindi	Uganda	1.53 (32)	PF: <i>Gorilla beringei beringei</i>	5, 6, 7
Ipassa	Gabon	1.15 (8)	PF: <i>Pan troglodytes troglodytes</i>	8
Oribi Gorge	South Africa	1.05 (26)	GS	9
Kibale	Uganda	1.50 (59)	PF: <i>Pan troglodytes schweinfurthii</i> + GS	10, 11
Gashaka	Nigeria	1.30 (73)	PF: <i>Pan troglodytes ellioti</i>	11
Tai	Ivory Coast	0.94 (44)	PF: <i>Pan troglodytes verus</i>	11
Salonga	Democratic Republic of Congo	1.23 (73)	PF: <i>Pan paniscus</i>	11
Tiwai	Sierra Leone	1.74 (29)	PF: <i>Piliocolobus badius</i> , <i>Procolobus verus</i> , <i>Colobus polykomos</i> + GS	12, 13
KwaZulu-Natal	South-Africa	1.31 (30)	GS	14
Udzungwa Mountains	Tanzania	1.52 (44)	PF: <i>Cercocebus sanjei</i>	15
Korup	Cameroon	1.44 (3)	PF: <i>Piliocolobus preussi</i>	16
Nyungwe	Rwanda	1.07 (23)	GS	17
Bulindi	Uganda	1.03 (41)	PF: <i>Pan troglodytes schweinfurthii</i>	18

Muara Gembong	Indonesia	1.84 (8)	PF: <i>Trachypithecus auratus</i>	19
Kuala Lompat	Malaysia	1.21 (8)	GS	20
Sepilok	Malaysia	1.34 (18)	PF: <i>Presbytis rubicunda chrysea</i> + GS	20, 21
Kutai	Indonesia	0.90 (39)	PF: <i>Pongo pygmaeus morio</i> , <i>Presbytis hosei canicrus</i>	21, 22
Sibaliw	Philippines	0.81 (49)	GS	Luft dataset S1
Gunung Palung	Indonesia	1.52 (85)	PF: <i>Pongo pygmaeus wurmbii</i>	23
Tuanan	Indonesia	0.99 (180)	PF: <i>Pongo pygmaeus wurmbii</i>	24
Tanjung Puting	Indonesia	0.83 (22)	PF: <i>Nasalis larvatus larvatus</i>	25
Fanjing Mountain	China	0.91 (5)	PF: <i>Rhinopithecus brelichi</i>	25
Tangkoko	Indonesia	1.05 (58)	PF: <i>Macaca nigra</i>	Kinnaird dataset S1
Phu Khieo	Thailand	1.22 (46)	PF: <i>Macaca assamensis assamensis</i>	Schülke dataset S1
Khao Yai	Thailand	1.16 (29)	PF: <i>Hylobates lar entelloides</i>	26
Kon Ka Kihn	Vietnam	1.33 (11)	PF: <i>Pygathrix cinerea</i>	27
Qianjiaping	China	1.48 (14)	PF: <i>Rhinopithecus roxellana hubeiensis</i>	28
Lore Lindu	Indonesia	0.86 (13)	PF: <i>Macaca tonkeana</i>	29
Silent Valley	India	1.49 (13)	PF: <i>Macaca silenus</i>	30
Sikkim	India	0.75 (19)	GS	31
Aichi	Japan	1.22 (5)	PF: <i>Macaca fuscata fuscata</i>	32
Madagascar				
Mandena	Madagascar	0.90 (207)	PF: <i>Cheirogaleus medius</i> + <i>Cheirogaleus major</i> + <i>Eulemur collaris</i> + <i>Hapalemur meridionalis</i> + <i>Microcebus ganzhornii</i> + GS	33, 34, 35, Campera & Balestri dataset S1
Ste Luce	Madagascar	0.90 (267)	PF: <i>Cheirogaleus medius</i> + <i>Eulemur collaris</i> + GS	33, 36, Campera & Balestri

				dataset S1
Kirindy	Madagascar	0.97 (53)	PF: <i>Propithecus verreauxi</i> + GS	33, 37, 38
Ranomafana	Madagascar	1.00 (51)	PF: <i>Propithecus edwardsi</i> , <i>Microcebus rufus</i>	33, 39
Sahamalaza	Madagascar	1.24 (67)	GS	33
Anjamena	Madagascar	0.88 (25)	PF: <i>Eulemur mongoz</i>	40
Tsinjoarivo	Madagascar	1.43 (22)	PF: <i>Propithecus diadema</i>	41
Ampijoroa	Madagascar	0.99 (3)	PF: <i>Eulemur fulvus</i>	42
Betampona	Madagascar	1.06 (84)	PF: <i>Varecia variegata variegata</i>	43
New World				
Los Tuxtlas	Mexico	1.34 (11)	PF: <i>Alouatta palliata mexicana</i>	44
Cockscomb Basin	Belize	1.33 (16)	PF: <i>Alouatta pigra</i>	45
Barro Colorado Island	Panama	1.66 (14)	GS	46, 47
Hato Masaguaral	Venezuela	1.12 (9)	PF: <i>Alouatta macconnelli</i>	48
Lago Guri	Venezuela	1.47 (19)	PF: <i>Pithecia pithecia</i> + 3 fruits not eaten	49
Nouragues	French Guiana	0.79 (14)	GS	50
San Cayetano / Isla Brasileira	Argentina	1.60 (3)	PF: <i>Alouatta caraya</i>	33, 51
Lemos Maia	Brasil	1.18 (22)	PF: <i>Callicebus moloch</i>	52
Finca la Luz	Nicaragua	1.41 (14)	PF: <i>Alouatta palliata palliata</i>	53
Monkey river	Belize	1.56 (9)	PF: <i>Alouatta pigra</i>	54
Guarayos	Bolivia	0.96 (28)	PF: <i>Ateles chamek</i>	55
Lomas Barbudal	Costa Rica	1.33 (64)	PF: <i>Cebus capucinus capucinus</i>	33
Tinigua	Columbia	1.28 (53)	PF: <i>Lagothrix lagotricha</i>	33
Raleighvallen	Suriname	1.17 (13)	PF: <i>Sapajus apella apella</i>	33
Yasuni'	Ecuador	1.59 (33)	PF: <i>Alouatta seniculus juara</i> + NPF	33
Parque Estadual Carlos Botelho	Brasil	1.94 (4)	PF: <i>Brachyteles arachnoides</i>	56
Finca Merenberg	Columbia	0.73 (27)	GS	57
El Caura	Venezuela	1.19 (44)	PF: <i>Ateles belzebuth</i>	58

Corcovado	Costa Rica	1.48 (10)	GS	59
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Supplementary Table S2. Model results for the Generalized Least Square model comparing the nitrogen in fruits between Madagascar, Old World and New World, not controlling for spatial autocorrelation (GLS_{nsp}), and corresponding null model (only-intercept model). SE = standard error; Δ AIC = difference in AIC from the best model.

Model	Terms	Estimate	SE	p-value	Δ AIC
GLS _{nsp}	Intercept (Madagascar)	0.976	0.063	0.000	0
	Old World	0.276	0.079	0.003	
	New World	0.304	0.098	0.001	
Null model	Intercept	1.179	0.036	0.000	8.12

Supplementary Table S3. Tukey post-hoc test for the Generalized Least Square model (GLS_{nsp}) results for the Generalized Least Square model comparing the nitrogen in fruits between Madagascar, Old World and New World, not controlling for spatial autocorrelation.

Post-hoc comparison	Estimate	SE	p-value
New World - Madagascar	0.304	0.098	0.005
Old World - Madagascar	0.276	0.079	0.001
Old World – New World	-0.028	0.088	0.945

Supplementary Table S4. Mean nitrogen concentration of all plant food items consumed by the primate species in the Old World, Madagascar, and the New World.

Species	Site	Mean % Nitrogen concentration in food (sample size)	Source
Old World			
<i>Cercocebus sanjei</i>	Udzungwa Mountain	2.07 (96)	15
<i>Cercocebus torquatus</i>	Campo	1.40 (5)	2
<i>Cercopithecus ascanius schmidtii</i>	Kibale	2.70 (18)	10
<i>Cercopithecus mitis ssp.</i>	Kibale & Zomba Plateau	1.85 (82)	10, 60
<i>Ptilocolobus preussi</i>	Korup	1.43 (17)	16
<i>Colobus guereza</i>	Kakamega	3.30 (22)	61
<i>Colobus polykomos</i>	Tiwai	2.90 (25)	12

<i>Gorilla beringei beringei</i>	Bwindi & Virunga	1.94 (126)	6, 7
<i>Gorilla gorilla gorilla</i>	Lope, Bai Hokou & Campo	1.63 (169)	1, 3, 4
<i>Hylobates lar entelloides</i>	Khao Yai	1.00 (16)	26
<i>Lophocebus albigena</i>	Kibale	2.60 (18)	10
<i>Macaca assamensis assamensis</i>	Phu Khieo	1.22 (58)	Schülke dataset S1
<i>Macaca fuscata fuscata</i>	Aichi	1.27 (16)	32
<i>Macaca nigra</i>	Tangkoko	1.05 (58)	Kinnaird dataset S1
<i>Nasalis larvatus larvatus</i>	Labuk Bay, Tanjung Puting & Lower Kinabatangan	1.41 (39)	62, 63, 64
<i>Pan troglodytes schweinfurthii</i>	Kibale, Bulindi	1.43 (45)	2, 18
<i>Pongo pygmaeus ssp.</i>	Kutai, Tanjung, Cabang Panti, & Tuanan	1.26 (385)	22, 23, 24, 65
<i>Presbytis siamensis siamensis</i>	Kuala Lompat	1.40 (12)	20
<i>Presbytis rubicunda chrysea</i>	Sepilok & Lower Kinabatangan	2.04 (36)	21, 66
<i>Ptilocolobus tephrosceles</i>	Kibale	3.63 (63)	67
<i>Procolobus verus</i>	Tiwai	2.80 (5)	68, 69
<i>Pygathrix cinerea</i>	Kon Ka Kihn	1.81 (33)	27
<i>Rhinopithecus bieti</i>	Mt Longma	1.76 (9)	70
<i>Rhinopithecus roxellana hubeiensis</i>	Qianjiaping	1.80 (117)	28
<i>Semnopithecus hector</i>	Rajaji	2.40 (16)	71
<i>Trachypithecus auratus</i>	Java	2.00 (13)	72
Madagascar			
<i>Avahi peyrierasi</i>	Ranomafana	2.50 (5)	73
<i>Avahi meridionalis</i>	Ste Luce	1.14 (47)	74
<i>Cheirogaleus major</i>	Mandena	0.90 (77)	34
<i>Cheirogaleus medius</i>	Mandena & Ste Luce	0.87 (108)	34, 36
<i>Eulemur collaris</i>	Mandena & Ste Luce	1.01 (176)	36, 75, Campera & Balestri dataset S1
<i>Eulemur flavifrons</i>	Sahamalaza	1.60 (88)	33
<i>Eulemur fulvus</i>	Ampijoroa	2.07 (8)	42
<i>Eulemur macaco</i>	Ampasikely	1.70 (23)	76
<i>Eulemur mongoz</i>	Anjamena	1.10 (46)	40
<i>Eulemur rufifrons</i>	Kirindy	1.00 (20)	37

<i>Hapalemur alaotrensis</i>	Alaotra	2.10 (15)	77
<i>Hapalemur aureus</i>	Ranomafana	3.20 (63)	33
<i>Hapalemur griseus</i>	Ranomafana	3.40 (40)	33
<i>Hapalemur meridionalis</i>	Mandena	1.37 (141)	35, 78
<i>Prolemur simus</i>	Ranomafana	2.30 (141)	33
<i>Indri indri</i>	Mantadia	1.70 (10)	79
<i>Lepilemur ruficaudatus</i>	Kirindy	2.40 (194)	80
<i>Microcebus ganzhornii</i>	Mandena	0.90 (77)	33, 34
<i>Microcebus rufus</i>	Ranomafana	0.90 (12)	39
<i>Propithecus diadema</i>	Tsinjoarivo & Mantadia	2.30 (87)	41, 79
<i>Propithecus edwardsi</i>	Ranomafana	2.00 (392)	33
<i>Propithecus verreauxi</i>	Kirindy	2.21 (260)	33, 38
<i>Varecia variegata variegata</i>	Betampona	1.30 (122)	43
New World			
<i>Alouatta caraya</i>	San Cayetano & Isla Brasilera	2.59 (46)	33, 51
<i>Alouatta palliata mexicana</i>	Finca la Luz, Los Tuxlas, Barro Colorado Island & La Suerte	2.25 (134)	44, 46, 81
<i>Alouatta pigra</i>	Pantanos de Centla, Monkey river, Cockscomb Basin	2.95 (173)	45, 54, 82
<i>Alouatta seniculus juara</i>	Yasuni'	2.30 (124)	33
<i>Alouatta macconnelli</i>	Hato Masaguaral	2.35 (37)	48
<i>Ateles belzebuth</i>	El Caura	1.35 (49)	58
<i>Ateles chamek</i>	Guarayos Forest Reserve	1.64 (44)	55
<i>Ateles geoffroyi ornatus</i>	Barro Colorado Island	1.90 (4)	46
<i>Brachyteles arachnoides</i>	Parque Estadual Carlos Botelho	2.20 (10)	56
<i>Callicebus moloch</i>	Mata Atlantica	1.60 (32)	52
<i>Cebus capucinus</i>	Barro Colorado Island & Barbudal	1.39 (68)	33, 46
<i>Lagothrix lagotricha</i>	Tinigua	1.30 (53)	83

Supplementary Table S5. Selection of best fit models in the generalized least square regression testing the effect of regions and fruit nitrogen (N) on the proportion of frugivorous primates and the average frugivory.

Model	df	AIC	Delta
pF50~N*Region	8	-176.984	0
pF50~1	3	-164.079	12.904
pF50~N	4	-162.446	14.538
pF50~Region	5	-160.922	16.062
aveFruit~N*Region	8	416.228	0
aveFruit~Region	5	432.531	16.303
aveFruit~1	3	442.221	25.993
aveFruit~N	4	444.112	27.885

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