

Genetic connectivity across marginal habitats: the elephants of the Namib Desert

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Supporting information

Supporting information references

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Supplementary Table S1. Samples used in this study.

Sample ID	Sex	Desert or not	Collection date	Sample	Group	CR haplotype	GenBank No.	Coordinates		Sample collection location
NA4651	F	(not desert)	1994	Tissue	Etosha	H63	JQ438544	-19.2043	16.191933	Aus Fountain, Etosha National Park
NA4652	F	(not desert)	1994	Tissue	Etosha	H63	JQ438545	-19.2043	16.191933	Aus Fountain, Etosha National Park
NA4653	M	(not desert)	1994	Tissue	Etosha	H63	JQ438546	-19.2043	16.191933	Aus Fountain, Etosha National Park
NA4655	M	(not desert)	1994	Tissue	Etosha	H62	JQ438547	-19.2379	16.121017	Oilfantsbad, Etosha
NA4656	F	(not desert)	1994	Tissue	Etosha	H63	JQ438548	-19.2379	16.121017	Oilfantsbad, Etosha
NA4657	M	(not desert)	1994	Tissue	Etosha	H63	JQ438549	-19.2379	16.121017	Oilfantsbad, Etosha
NA4658	F	(not desert)	1994	Tissue	Etosha	H63	JQ438550	-19.2379	16.121017	Oilfantsbad, Etosha
NA4659	M	(not desert)	1994	Tissue	Etosha	H63	JQ438551	-19.2379	16.121017	Oilfantsbad, Etosha
NA4660	M	(not desert)	1994	Tissue	Etosha	H63	JQ438552	-19.2043	16.191933	Aus Fountain, Etosha National Park
NA4661	F	(not desert)	1994	Tissue	Etosha	H63	JQ438553	-19.2379	16.121017	Oilfantsbad, Etosha
NA4662	M	(not desert)	1994	Tissue	Etosha	H62	JQ438554	-19.2043	16.191933	Aus Fountain, Etosha National Park
NA4663	F	(not desert)	1994	Tissue	Etosha	H62	JQ438555	-19.2043	16.191933	Aus Fountain, Etosha National Park
NA4664	M	(not desert)	1994	Tissue	Etosha	H63	JQ438556	-19.2043	16.191933	Aus Fountain, Etosha National Park
NA4665	M	(not desert)	1994	Tissue	Etosha	H63	JQ438557	-19.2043	16.191933	Aus Fountain, Etosha National Park
NA4666	F	(not desert)	1994	Tissue	Etosha	H63	JQ438558	-19.2043	16.191933	Aus Fountain, Etosha National Park
NA4667	M	(not desert)	1994	Tissue	Etosha	H62	JQ438559	-18.586367	16.887167	Mashara Lodge, 8 km from the Lindequist Gate of the Etosha National Park
NA4668	M	(not desert)	1994	Tissue	Etosha	H63	JQ438560	-18.586367	16.887167	Mashara Lodge, 8 km from the Lindequist Gate of the Etosha National Park
NA4669	M	(not desert)	1994	Tissue	Etosha	H62	JQ438561	-18.586367	16.887167	Mashara Lodge, 8 km from the Lindequist Gate of the Etosha National Park
NA4670	M	(not desert)	1994	Tissue	Etosha	H62	JQ438562	-18.586367	16.887167	Mashara Lodge, 8 km from the Lindequist Gate of the Etosha National Park
NA4671	M	(not desert)	1994	Tissue	Etosha	H62	JQ438563	-18.586367	16.887167	Mashara Lodge, 8 km from the Lindequist Gate of the Etosha National Park
NA4672	F	(not desert)	1994	Tissue	Etosha	H62	JQ438564	-18.586367	16.887167	Mashara Lodge, 8 km from the Lindequist Gate of the Etosha National Park
NA4673	M	(not desert)	1994	Tissue	Etosha	H63	JQ438565	-18.586367	16.887167	Mashara Lodge, 8 km from the Lindequist Gate of the Etosha National Park
NA4674	F	(not desert)	1994	Tissue	Etosha	H62	JQ438566	-18.6175	16.988883	Kameeldoring Pan, Etosha National Park
NA4675	M	(not desert)	1994	Tissue	Etosha	H63	JQ438567	-18.586367	16.887167	Mashara Lodge, 8 km from the Lindequist Gate of the Etosha National Park
NA4677	M	(not desert)	1994	Tissue	Etosha	H62	JQ438568	-18.6175	16.988883	Kameeldoring Pan, Etosha National Park
NA4678	M	(not desert)	1994	Tissue	Etosha	H62	JQ438569	-18.6175	16.988883	Kameeldoring Pan, Etosha National Park
NA4679	N/A	(not desert)	1994	Tissue	Etosha	H63	JQ438570	-18.6175	16.988883	Kameeldoring Pan, Etosha National Park
NA4680	M	(not desert)	1994	Tissue	Etosha	H63	JQ438571	-18.942617	16.7017	Batia, Etosha National Park
NA4681	M	(not desert)	1994	Tissue	Etosha	H62	JQ438572	-18.942617	16.7017	Batia, Etosha National Park
NA4685	F	(not desert)	1994	Tissue	Huab River	H62	JQ438573	-20.363681	14.937762	Khorixas
NA4686	F	(not desert)	1994	Tissue	Huab River	H62	JQ438574	-20.372065	14.959329	Damara Mopane Lodge
NA4687	F	(not desert)	1994	Tissue	C. Kunene	H62	JQ438575	-19.857517	13.843031	Krone Canyon
NA4688	M	(not desert)	1994	Tissue	C. Kunene	H62	JQ438576	-19.857517	13.843031	Krone Canyon
NA4689	M	(not desert)	1994	Tissue	Etosha	H62	JQ438577	-19.174183	15.914417	Okakukejo, Kunene
NA4690	M	(not desert)	1994	Tissue	Etosha	H63	JQ438578	-19.174183	15.914417	Okakukejo, Kunene
NA4691	M	(not desert)	1994	Tissue	Etosha	H62	JQ438579	-19.174183	15.914417	Okakukejo, Kunene
NA4692	M	(not desert)	1994	Tissue	Etosha	H63	JQ438580	-19.174183	15.914417	Okakukejo, Kunene
NA4695	M	(not desert)	1994	Tissue	Etosha	H62	JQ438581	-19.174183	15.914417	Okakukejo, Kunene
NA4696	M	(not desert)	1994	Tissue	Etosha	H63	JQ438582	-19.174183	15.914417	Okakukejo, Kunene
NA4697	M	(not desert)	1994	Tissue	Etosha	H62	JQ438583	-19.174183	15.914417	Okakukejo, Kunene
NA4698	M	(not desert)	1994	Tissue	Etosha	H63	JQ438584	-19.174183	15.914417	Okakukejo, Kunene
NA4699	M	(not desert)	1994	Tissue	C. Kunene	H62	JQ438585	-19.627183	14.842543	Kamanjab
NA4701	N/A	(not desert)	1994	Tissue	Etosha			-19.033333	16.483333	Helio, National Park
NA4702	M	(not desert)	1994	Tissue	Etosha	H63	JQ438586	-19.2379	16.121017	Oilfantsbad, Etosha
NA4703	F	(not desert)	1994	Tissue	Etosha	H62	JQ438587	-18.674494	15.577669	North of Pan Point, Etosha National Park
NA4704	M	(not desert)	1994	Tissue	Etosha	H03	JQ438588	-18.78333	15.583333	Pan Point, Etosha National Park
NA4705	M	(not desert)	1994	Tissue	Etosha	H62	JQ438589	-18.78333	15.583333	Pan Point, Etosha National Park
NA4706	M	(not desert)	1994	Tissue	Etosha	H63	JQ438590	-18.966667	15.31667	Sonderkop, Etosha Restricted Area
NA4707	N/A	(not desert)	1994	Tissue	Etosha	H62	JQ438591	-18.966667	15.31667	Sonderkop, Etosha Restricted Area
NA4708	M	(not desert)	1994	Tissue	Etosha	H62	JQ438592	-18.966667	15.05	Teespoed, Etosha Restricted Area
NA4709	N/A	(not desert)	1994	Tissue	Etosha			-18.966667	15.05	Teespoed, Etosha Restricted Area
NA4710	M	(not desert)	1994	Tissue	Etosha	H62	JQ438593	-18.966667	15.05	Teespoed, Etosha Restricted Area
NA4711	N/A	(not desert)	1994	Tissue	Etosha			-18.956623	14.963722	Tobiroen, Etosha National Park
NA4712	N/A	(not desert)	1994	Tissue	Etosha			-18.956623	14.963722	Tobiroen, Etosha National Park
NA4713	M	(not desert)	1994	Tissue	Etosha			-18.85	15.03333	Nerens, Etosha National Park
NA4716	N/A	(not desert)	1994	Tissue	C. Kunene	H58	JQ438594	-19.316667	13.966667	Khowarib Schlucht, Kunene, Namibia
NA4717	N/A	(not desert)	1994	Tissue	C. Kunene	H62	JQ438595	-19.316667	13.966667	Khowarib Schlucht, Kunene, Namibia
NA4720	N/A	(not desert)	1994	Tissue	Etosha	H62	JQ438596			Etosha
NA4721	F	(not desert)	1994	Tissue	Etosha	H63	JQ438597	-19.213434	16.059196	Gemsbokvlakte, Oshikoto

Sample ID	Sex	Desert or not	Collection date	Sample	Group	CR haplotype	GenBank No.	Coordinates		Sample collection location
NA4722	M	(not desert)	1994	Tissue	Etosha	H63	JQ438598	-19.213434	16.059196	Gemsbokvlakte, Oshikoto
NA5122	N/A	Desert	2002	Dung	Desert	H62	JQ438599	-19.383333	13.1	Hoanib River
NA5113	N/A	Desert	2002	Dung	Desert	H63	JQ438600	-19.383333	13.1	Hoanib River
NA5117	N/A	Desert	2002	Dung	Desert	H62	JQ438601	-19.383333	13.1	Hoanib River
NA5116	N/A	Desert	2002	Dung	Desert	H63	JQ438602	-19.383333	13.1	Hoanib River
NA5014	M	(not desert)	7/8/04	Dung	Ugab River	H62	JQ438603	-20.941311	14.79774	Ugab River
NA5015	F	(not desert)	7/8/04	Dung	Ugab River	H62	AF106235	-20.941311	14.79774	Ugab River
NA5016	M	(not desert)	7/8/04	Dung	Ugab River	H62	AF106236	-20.941311	14.79774	Ugab River
NA5017	M	(not desert)	6/6/04	Dung	Ugab River	H62	AF106237	-20.941311	14.79774	Ugab River
NA5018	M	(not desert)	6/6/04	Dung	Ugab River	H62	AF106238	-20.941311	14.79774	Ugab River
NA5019	M	(not desert)	9/6/04	Dung	Ugab River	H62	AF106211, AF527682, AY742800, AY741325, AY741323*	-20.941311	14.79774	Ugab River
NA5020	M	(not desert)	9/6/04	Dung	Ugab River	H62	AF106211, AF527682, AY742800, AY741325, AY741323*	-20.941311	14.79774	Ugab River
NA5022	M	(not desert)	9/8/04	Dung	Huab River	H62	AF106211, AF527682, AY742800, AY741325, AY741323*	-20.399175	15.00424	Huab
NA5024	M	(not desert)	5/17/04	Dung	Ugab River	H62	AF106211, AF527682, AY742800, AY741325, AY741323*	-20.941311	14.79774	Sorris-Sorris
NA5028	M	(not desert)	9/12/04	Dung	Huab River	H62	AF106211, AF527682, AY742800, AY741325, AY741323*	-20.439938	14.619192	Aba-Huab River
NA5029	M	(not desert)	13/09/04	Dung	Huab River	H63	AF106239*	-20.439938	14.619192	Aba-Huab River
NA5030	F	(not desert)	9/13/04	Dung	Huab River	H62	AF106211, AF527682, AY742800, AY741325, AY741323*	-20.439938	14.619192	Aba-Huab River
NA5032	F	(not desert)	9/14/04	Dung	Huab River	H62	AF106211, AF527682, AY742800, AY741325, AY741323*	-20.399175	15.00424	Huab
NA5099	M	(not desert)	3/14/03	Dung	Huab River	H03	AF106228, AF106234, AY359275*	-20.399175	15.00424	Huab
NA5202	M	(not desert)	2002	Blood	Etosha	H63	AF106239*	-19.346838	14.40247	Hobaterre Concession, Kunene
NA5203	M	(not desert)	2002	Blood	Etosha	H62	AF106211, AF527682, AY742800, AY741325, AY741323*	-19.346838	14.40247	Hobaterre Concession, Kunene
NA5204	F	(not desert)	2002	Blood	Etosha	H63	AF106239*	-19.346838	14.40247	Hobaterre Concession, Kunene
NA5205	M	Desert	2002	Blood	Desert	H62	AF106211, AF527682, AY742800, AY741325, AY741323*	-18.773699	12.95075	Purros
NA5206	M	Desert	2002	Blood	Desert	H62	AF106211, AF527682, AY742800, AY741325, AY741323*	-18.773699	12.95075	Purros
NA5207	M	Desert	2002	Blood	Desert	H63	AF106239*	-18.773699	12.95075	Purros
NA5208	F	Desert	2002	Blood	Desert	H62	AF106211, AF527682, AY742800, AY741325, AY741323*	-18.773699	12.95075	Purros

CR (control region) haplotype designations follow those of Johnson et al. (2007).

*316 bp CR sequences matched with the previously reported sequences (Debruyne 2005; Debruyne et al. 2003; Eggert et al. 2002; Nyakaana et al. 2002) (listed in Johnson et al. 2007).

Supplementary Table S2. Characterization of microsatellite loci genotyped in Namibian elephants.

Locus	HWE	Total				Non-desert localities				Desert elephants				References
	<i>p</i> -value	<i>n</i>	Allele No.	<i>H_o</i>	<i>H_e</i>	<i>n</i>	Allele No.	<i>H_o</i>	<i>H_e</i>	<i>n</i>	Allele No.	<i>H_o</i>	<i>H_e</i>	
LafMS0		5		0.4	0.5	5		0.4	0.5			0.7	0.5	
3	0.188	5	3	9	3	1	3	7	3	4	2	5	4	Nyakaana and Arctander 1998
LafMS0		5		0.2	0.3	5		0.2	0.2			0.5	0.4	
4	0.623	5	4	7	0	1	4	5	9	4	3	0	6	Nyakaana and Arctander 1998
		5		0.9	0.7	5		0.9	0.7			1.0	0.8	
FH39	0.720	5	9	3	8	1	9	2	8	4	6	0	9	Comstock et al. 2000
		5		0.7	0.6	5		0.7	0.6			0.7	0.6	
FH40	0.106	5	5	3	6	1	5	3	7	4	3	5	1	Comstock et al. 2000
		5		0.5	0.5	5		0.5	0.5			0.7	0.5	
FH48	0.345	5	7	8	4	1	7	7	2	4	2	5	4	Comstock et al. 2000
		5		0.5	0.5	5		0.5	0.5			0.7	0.5	
FH60	1.000	5	3	8	6	1	3	7	7	4	2	5	4	Comstock et al. 2000
		5		0.4	0.4	5		0.4	0.4			0.7	0.5	
FH67	0.530	5	3	5	8	1	3	3	8	4	2	5	4	Comstock et al. 2000
		5		0.3	0.4	5		0.3	0.4			0.5	0.4	
FH71	0.013	5	3	8	4	1	3	7	5	4	2	0	3	Comstock et al. 2000
		5		0.7	0.6	5		0.7	0.7			0.5	0.4	
FH94	0.575	4	5	0	9	0	5	2	0	4	2	0	3	Comstock et al. 2000
		5		0.6	0.6	4		0.6	0.6			0.7	0.7	
FH102	0.704	2	5	3	7	8	4	3	7	4	4	5	5	Comstock et al. 2000
		5		0.4	0.4	5		0.4	0.4			0.6	0.5	
EMX-4	1.000	4	2	3	4	1	2	1	4	3	2	7	3	Fernando et al. 2001
		5		0.8	0.8	5		0.7	0.8			1.0	0.8	
FH127	0.774	4	11	0	1	0	10	8	2	4	5	0	6	Comstock et al. 2002
		5		0.7	0.7	4		0.7	0.7			0.7	0.6	
FH129	0.428	3	6	4	0	9	6	3	1	4	3	5	1	Comstock et al. 2002
		5		0.8	0.8	5		0.8	0.8			0.7	0.8	
FH153	0.654	4	11	1	2	0	11	2	2	4	5	5	6	Comstock et al. 2002
		5		0.8	0.8	5		0.8	0.8			1.0	0.9	
LaT05	0.257	4	13	5	8	0	12	4	7	4	7	0	6	Archie et al. 2003
LaT06	0.000*	—	—	—	—	—	—	—	—	—	—	—	—	Archie et al. 2003
		5		0.3	0.3	5		0.3	0.3			0.2	0.2	
LAF11	1.000	5	2	5	3	1	2	7	5	4	2	5	5	Ishida et al. 2011
		5		0.5	0.5	5		0.4	0.5			0.7	0.5	
LAF13	1.000	5	2	1	0	1	2	9	0	4	2	5	4	Ishida et al. 2011
		5		0.6	0.6	4		0.6	0.6			1.0	0.7	
LAF29	0.177	3	6	4	3	9	6	1	2	4	4	0	5	Ishida et al. 2011

LAF37	0.094	5		0.5	0.6	5		0.5	0.6			0.7	0.6	Ishida et al. 2011
FH19	0.000*	4	4	7	7	0	4	6	7	4	3	5	1	Comstock et al. 2000
EMX-5	Monomorphic	-	-	-	-	-	-	-	-	-	-	-	-	Fernando et al. 2001
Mean			5.47	0.6	0.6		5.32	0.5	0.6		3.21	0.7	0.6	
<i>s.d.</i>			3.32	0.1	0.1		3.13	0.1	0.1		1.55	0.2	0.1	

Asterisks indicate markers showing significant deviation from HWE after Bonferroni correction ($p < 0.002$). Markers LaT06, FH19, and EMX-5 were removed from the subsequent population analyses.

n: sample size, Ho: observed heterozygosity, He: expected heterozygosity.

Supplementary Table S3. Haplotypes identified in Namibian elephants using 4258 bp mtDNA sequences.

Haplotype	Namibia		Other countries
	Etosha	Desert	
NA1	14	2	0
NA2	13	0	0
NA3	9	0	0
NA4	7	1	41*
NA5	6	0	0
NA6	5	0	0
NA7	1	0	0
NA8	1	0	0
NA9	1	0	0

Haplotype names follow those of Figure 2B.

*The NA4 haplotype was also detected in elephants from Aberdares ($n = 1$) in Kenya; Ngorongoro ($n = 3$) and Tarangire ($n = 21$); in Tanzania; Chobe ($n = 12$), Mashatu ($n = 1$), Savuti ($n = 1$) in Botswana; and Zambezi ($n = 2$) in Zimbabwe.

Supplementary Table S4. Haplotypes identified in Namibian elephants using 316 bp mitochondrial DNA sequences.

Haplotype	Caprivi	Deser t	C. Kunene	Etosh a	Hua b	Uga b	Other countries*
H03	0	0	0	1	1	0	Botswana, Zimbabwe
H58	0	0	1	0	0	0	Kenya, Tanzania
H62	0	5	4	23	6	8	Botswana, Kenya, South Africa, Tanzania, Uganda, Zimbabwe
H63	0	3	0	27	1	0	none
H74	1	0	0	0	0	0	none
H75	5	0	0	0	0	0	none
H76	1	0	0	0	0	0	none
H77	1	0	0	0	0	0	none

Haplotype designations follow those of Johnson et al. (2007).

The Caprivi Strip data is from Nyakaana et al. (2002).

*Countries other than Namibia in which the haplotype has been detected.

Figure S1. Spatial autocorrelation results for males ($n = 39$) and females ($n = 11$) were conducted separately using the software GenALEX 6.5 . Samples for which the sex was unknown were not included in the analyses. Geographic distances were calculated for all pairs of elephants, then the geographic distances were divided into quintiles and the program was run using 999 random permutations and 1,000 bootstraps. r : spatial autocorrelation coefficient. U : upper 95% randomization limits of r . L : lower 95% randomization limits of r . Neither males nor females showed significant spatial autocorrelation.

Figure S2. (A) Structure analysis using 17 microsatellite genotypes of 55 Namibian Etosha elephants did not partition the dataset between desert and other elephants. The program was run using values of K from 1 to 10. Each analysis was run for at least 1 million Markov chain Monte Carlo generations following a burn-in of at least 100,000 steps using an admixture-correlated model. The results are shown for $K = 2$, $K = 3$, and $K = 4$. (B) For the dataset of 17 microsatellites genotypes, STRUCTURE analyses were also conducted comparing the 4 desert elephants to 4 randomly chosen Etosha elephants. Results are shown for $K = 2$ for several different sets of randomly chosen Etosha elephants.

Figure S3. Map showing the geographic distribution of elephant sampling locations across Africa for which mtDNA sequences were available for comparison with the current dataset. The map and associated information were previously published by Ishida et al. (2013) and are reproduced here as permitted under the terms of the Creative Commons Attribution License ([http://onlinelibrary.wiley.com/journal/10.1111/\(ISSN\)1752-4571/homepage/open_access_license_and_copyright.htm](http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)1752-4571/homepage/open_access_license_and_copyright.htm)).

Colors on the map represent mitochondrial DNA subclades as indicated in the key and described in Ishida et al. (2013). The large pie charts represent localities from which elephants have been sequenced for 4258 bp of mitochondrial DNA (from part of *ND5* to the control region), see Ishida et al. (2013). Locations in tropical forest habitats are: DS-Dzanga Sangha, Central African Republic; OD-Odzala, Republic of Congo; BF-Bili Forest, Democratic Republic of Congo; LO-Lope, Gabon; and SL-Sierra Leone (one zoo individual). Savanna locations: CH-Chobe, MA-Mashatu, SA-Savuti in Botswana; BE-Benoue, WA-Waza in Cameroon; AB-Aberdares, AM-Amboseli, KE-Central Kenya/Laikipia, MK-Mount Kenya in Kenya; NA-Northern Namibia/Etosha; KR-Kruger in South Africa; NG-Ngorongoro, SE-Serengeti, TA-Tarangire in Tanzania; HW-Hwange, SW-Sengwa, ZZ-Zambezi in Zimbabwe. GR-Garamba is located in the Guinea-Congolian/Sudanian transition zone of vegetation in D.R. Congo.

The small circles represent localities sampled by other previous mtDNA studies, from which mitochondrial control region sequences are available ; these are numbered as follows:

