

Acoustic variability among male gladiator frogs, *Boana goiana*
(Lutz, 1968) (Anura: Hylidae): an 18-year analysis across
several reproductive seasons

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Supplementary material

Table S1. Reference folder names in which the recordings of *Boana goiana* utilized in analysis are housed in Zoological Collection of the Universidade Federal de Goiás (ZUFG).

Reproductive season	Folder names
1996/1997	RPB8; RPB10
2000/2001	RPB21
2003/2004	RPB24; RPB25; RPB27
2005/2006	RPB28; RPB29; RPB32; RPB39; RPB41; RPB45
2006/2007	CA1; CA2; RPB23; RPB24; RPB45; RPB48; RPB48; RPB49; RPB52
2007/2008	RPB52; RPB53; RPB56; RPB57
2008/2009	05.04.2009; 06.05.2009; 07.05.2009; 01.09.2009; 12.05.2009
2011/2012	05.03.2012; 12.03.2012; 17.03.2012; 18.03.2012
2012/2013	16.01.2013; 27.01.2013; 31.01.2013; 16.02.2013; 04.03.2013; 09.03.2013; 10.03.2013; 15.03.2013; 16.03.2013; 18.03.2013
2013/2014	13.01.2014; 14.01.2014; 15.01.2014; 16.01.2014; 29.01.2014; 30.01.2014

Table S2. Models for the regressions for each acoustic parameter of the advertisement calls of *Boana goiana*.

Candidate models	AICc	wAICc
<i>Call duration</i>		
null	-370.065	0.3444
Temperature	-368.742	0.1777
Year	-368.312	0.1433
Body Size	-367.994	0.1223
Year, Temperature	-366.974	0.0734
Temperature, Body Size	-366.646	0.0623
Year, Body Size	-366.230	0.0506
Year, Temperature, Body Size	-364.882	0.0258
<i>Number of Pulses</i>		
Temperature	174.813	0.2486
Year, Temperature	175.278	0.1971
null	175.736	0.1567
Year	176.245	0.1215
Temperature, Body Size	176.685	0.0975
Year, Temperature, Body Size	177.369	0.0693
Body Size	177.491	0.0652
Year, Body Size	178.282	0.0445
<i>Pulse duration</i>		
Year, Body Size	-1223.704	0.5996
Year, Temperature, Body Size	-1221.875	0.2402
Year	-1220.334	0.1112
Year, Temperature	-1218.680	0.0486
Body Size	-1208.594	0.0003
Temperature, Body Size	-1206.674	0.0001
null	-1200.013	<0.0001
Temperature	-1198.277	<0.0001

Candidate models	AICc	wAICc
<i>Dominant Frequency</i>		
Year, Temperature, Body Size	2122.543	0.3363
Year, Body Size	2122.580	0.3301
Temperature, Body Size	2123.873	0.1729
Body Size	2124.020	0.1607
Year	2148.297	<0.0001
Year, Temperature	2149.272	<0.0001
null	2155.314	<0.0001
Temperature	2156.264	<0.0001
<i>Call Repetition Rate</i>		
Temperature	709.595	0.3041
null	710.288	0.2151
Temperature, Body Size	711.352	0.1263
Year, Temperature	711.626	0.1102
Body Size	712.121	0.0860
Year	712.302	0.0786
Year, Temperature, Body Size	713.305	0.0476
Year, Body Size	714.082	0.0323
<i>Pulse Repetition Rate</i>		
null	666.970	0.3599
Temperature	668.698	0.1517
Year	668.751	0.1477
Body Size	668.831	0.1419
Year, Temperature	670.510	0.0613
Temperature, Body Size	670.553	0.0600
Year, Body Size	670.733	0.0548
Year, Temperature, Body Size	672.491	0.0228

Table S3. Models for the regressions for each acoustic parameter of the aggressive calls of *Boana goiana*.

Candidate models	AICc	wAICc
<i>Call duration</i>		
Year	-409.644	0.2937
Year, Body Size	-408.426	0.1598
null	-408.170	0.1406
Body Size	-407.994	0.1288
Year, Temperature	-407.691	0.1106
Year, Body Size, Temperature	-406.520	0.0616
Temperature	-406.242	0.0536
Body Size, Temperature	-406.151	0.0512
<i>Number of Pulses</i>		
null	336.737	0.3387
Body Size	338.016	0.1787
Year	338.402	0.1473
Temperature	338.750	0.1238
Year, Body Size	339.949	0.0680
Body Size, Temperature	340.009	0.0660
Year, Temperature	340.448	0.0530
Year, Body Size, Temperature	341.984	0.0246
<i>Pulse duration</i>		
Year, Body Size	-1003.382	0.4381
Year, Body Size, Temperature	-1002.397	0.2678
Year	-1001.696	0.1885
Year, Temperature	-1000.363	0.0968
Body Size	-994.444	0.0050
Body Size, Temperature	-993.532	0.0032
null	-989.000	0.0003
Temperature	-987.596	0.0002

Candidate models	AICc	wAICc
<i>Dominant Frequency</i>		
Body Size	1522.178	0.3616
Year, Body Size	1522.781	0.2675
Body Size, Temperature	1523.206	0.2163
Year, Body Size, Temperature	1523.881	0.1543
Year	1538.169	0.0001
Year, Temperature	1539.940	0.0001
null	1540.994	<0.0001
Temperature	1542.753	<0.0001
<i>Call Repetition Rate</i>		
Year	697.118	0.5334
Year, Body Size	698.978	0.2104
Year, Temperature	699.242	0.1844
Year, Body Size, Temperature	701.145	0.0712
Body Size	712.475	0.0002
null	712.603	0.0002
Body Size, Temperature	714.608	<0.0001
Temperature	714.692	<0.0001
<i>Pulse Repetition Rate</i>		
Year	554.859	0.3542
null	556.157	0.1851
Year, Body Size	556.953	0.1243
Year, Temperature	556.991	0.1220
Body Size	557.834	0.0800
Temperature	558.255	0.0648
Year, Body Size, Temperature	559.119	0.0421
Body Size, Temperature	559.960	0.0276

Table S4. Mean value with standard deviation and standard error of the acoustic parameters for advertisement and aggressive calls recorded for the same population of *B. goiana* in the Silvânia National Forest, municipality of Silvânia, Goiás State, Brazil, across each sampled reproductive season. The standard error is show between parentheses.

Reproductive season	Call type	Call duration (s)	Number of pulses	Pulse duration (s)	Dominant frequency (Hz)	Pulse repetition rate	Call repetition rate	Number of males analyzed	Number of calls analyzed
1996/1997	Advertisement	0.298 ±0.087(0.029)	3 ±0.498(0.166)	0.048 ±0.008(0.003)	3202.207 ±71.750(23.917)	9.273 ±1.401(0.467)	3.531 ±2.261(0.754)	9	40
	Aggressive	0.254 ±0.040(0.015)	5 ±0.872(0.330)	0.021 ±0.002(0.001)	3189.360 ±53.933(20.385)	18.850 ±1.336(0.505)	12.649 ±6.306(2.383)	7	35
2000/2001	Advertisement	0.275 ±0.087(0.026)	3 ±0.370(0.111)	0.050 ±0.008(0.002)	3224.493 ±112.634(33.961)	9.623 ±1.857(0.560)	4.190 ±1.375(0.415)	11	55
	Aggressive	0.247 ±0.037(0.012)	5 ±0.769(0.256)	0.021 ±0.004(0.001)	3196.464 ±126.310(42.310)	18.364 ±1.835(0.612)	5.702 ±3.245(1.082)	9	42
2003/2004	Advertisement	0.361 ±0.071(0.024)	3 ±0.292(0.097)	0.044 ±0.005(0.002)	3131.400 ±98.871(32.957)	8.345 ±1.491(0.497)	4.398 ±2.111(0.704)	9	44
	Aggressive	0.300 ±0.044(0.018)	5 ±0.602(0.246)	0.015 ±0.004(0.002)	3158.200 ±75.987(31.022)	17.980 ±2.440(0.996)	4.589 ±2.496(1.019)	6	30
2005/2006	Advertisement	0.297 ±0.073(0.012)	3 ±0.391(0.064)	0.040 ±0.008(0.001)	3270.245 ±128.053(21.052)	9.497 ±1.499(0.246)	3.324 ±1.661(0.273)	37	167
	Aggressive	0.227 ±0.049(0.012)	4 ±0.876(0.212)	0.016 ±0.003(0.001)	3190.454 ±79.812(19.357)	19.295 ±1.630(1.052)	6.121 ±4.338(1.052)	21	80

Reproductive season	Call type	Call duration (s)	Number of pulses	Pulse duration (s)	Dominant frequency (Hz)	Pulse repetition rate	Call repetition rate	Number of males analyzed	Number of calls analyzed
2006/2007	Advertisement	0.315 ±0.061(0.010)	3 ±0.284(0.046)	0.043 ±0.015(0.002)	3241.780 ±126.697(20.288)	9.396 ±1.401(0.224)	3.725 ±1.728(0.277)	38	184
	Aggressive	0.248 ±0.049(0.009)	5 ±1.142(0.212)	0.018 ±0.005(0.001)	3258.928 ±130.193(24.176)	18.606 ±2.204(0.409)	2.799 ±1.952(0.362)	31	124
2007/2008	Advertisement	0.277 ±0.094(0.024)	3 ±0.460(0.119)	0.040 ±0.007(0.002)	3242.020 ±165.500(42.732)	10.333 ±2.108(0.544)	4.386 ±1.937(0.500)	15	74
	Aggressive	0.231 ±0.033(0.009)	5 ±0.718(0.192)	0.015 ±0.003(0.001)	3222.171 ±141.657(37.860)	19.849 ±1.673(0.447)	4.341 ±2.489(0.665)	15	69
2008/2009	Advertisement	0.323 ±0.075(0.020)	3± 0.442(0.118)	0.040 ±0.008(0.002)	3272.564 ±115.741(30.933)	9.167 ±1.490(0.398)	5.118 ±2.309(0.617)	14	69
	Aggressive	0.238 ±0.035(0.010)	4 ±0.588(0.170)	0.019 ±0.004(0.001)	3257.529 ±127.700(36.864)	18.091 ±1.659(0.479)	6.708 ±5.200(1.501)	12	55
2011/2012	Advertisement	0.292 ±0.082(0.018)	3 ±0.438(0.098)	0.038 ±0.007(0.002)	3277.882 ±70.160(15.688)	9.668 ±1.715(0.384)	3.868 ±1.921(0.429)	20	94
	Aggressive	0.232 ±0.048(0.015)	5 ±0.892(0.282)	0.013 ±0.003(0.001)	3240.776 ±81.607(25.807)	20.500 ±1.880(0.594)	4.872 ±3.978(1,258)	11	46
2012/2013	Advertisement	0.280 ±0.078(0.014)	3 ±0.414(0.073)	0.041 ±0.005(0.001)	3285.694 ±100.741(17.809)	10.099 ±1.694(0.300)	4.076 ±1.747(0.309)	33	160

Aggressive	0.232 ±0.045(0.010)	5 ±0.967(0.206)	0.016 ±0.004(0.001)	3252.200 ±89.975(19.183)	20.067 ±2.247(0.479)	5.663 ±4.615(0.984)	24	104
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Reproductive season	Call type	Call duration (s)	Number of pulses	Pulse duration (s)	Dominant frequency (Hz)	Pulse repetition rate	Call repetition rate	Number of males analyzed	Number of calls analyzed
2013/2014	Advertisement	0.332 ±0.047(0.016)	3 ±0.279(0.093)	0.034 ±0.008(0.003)	3295.833 ±75.454(25.151)	8.972 ±0.852(0.284)	3.589 ±1.922(0.641)	10	42
	Aggressive	0.230 ±0.024(0.008)	5 ±0.648(0.229)	0.010 ±0.003(0.001)	3277.734 ±70.857(25.052)	19.946 ±2.174(0.764)	3.401 ±2.391(0.845)	9	34
Total	Advertisement	0.301 ±0.076(0.005)	3 ±0.392(0.028)	0.042 ±0.010(0.001)	3254.917 ±118.159(8.462)	9.553 ±1.612(0.115)	3.914 ±1.856(0.133)	198	939
	Aggressive	0.240 ±0.044(0.004)	5 ±0.895(0.077)	0.017 ±0.005(<0.001)	3232.599 ±109.633(9.471)	19.207 ±2.068(0.179)	5.182 ±4.260(0.368)	146	620

Table S5. Coefficient of intra- individual variation with the minimum and maximum values and the inter-individual variation (in parentheses) of the acoustic parameters for advertisement and aggressive calls of *B. goiana*, recorded for each reproductive season in the same population in the Silvânia National Forest, municipality of Silvânia, Goiás State, Brazil and the ranges of temperature in the moment of recording and range of body size of individuals.

Reproductive season	Call type	Call duration	Number of pulses	Pulse duration	Dominant frequency	Pulse repetition rate	Temperature (°C) Range	Body size range
1996/1997	Advertisement	8.84 1.70 – 25.86 (28.72)	5.10 0.00 – 16.05 (18.31)	8.93 2.94 – 17.43 (16.92)	0.43 0.00 – 1.50 (2.11)	6.91 1.73 – 16.16 (15.00)	21.00 – 23.20	44.24 – 53.26
	Aggressive	10.14 3.47 – 23.12 (15.58)	11.76 0.00 – 22.01 (18.16)	10.61 4.74 – 20.71 (9.38)	0.97 0.00 – 1.50 (1.60)	5.37 2.93 – 9.64 (7.26)	21.00 – 23.20	44.24 – 53.26
2000/2001	Advertisement	19.20 1.21 – 45.61 (32.39)	12.16 0.00 – 23.30 (15.91)	12.86 4.02 – 24.40 (16.32)	1.65 0.00 – 4.98 (3.40)	12.01 1.23 – 27.23 (19.64)	19.00 – 25.00	34.67 – 65.03
	Aggressive	19.05 2.74 – 35.99 (15.27)	14.66 0.00 – 30.46 (17.10)	11.43 3.87 – 23.22 (19.49)	0.98 0.00 – 3.77 (3.84)	6.17 1.42 – 20.47 (10.53)	19.00 – 25.00	34.67 – 59.23
2003/2004	Advertisement	20.09 1.06 – 55.97 (19.52)	9.34 0.00 – 23.73 (10.07)	8.26 2.10 – 18.88 (11.63)	1.01 0.00 – 1.90 (3.23)	10.46 1.03 – 26.27 (17.46)	23.00 – 26.20	38.26 – 59.03
	Aggressive	9.6 0.84 – 20.33 (14.53)	10.20 0.00 – 24.52 (11.29)	12.87 8.37 – 17.98 (25.75)	0.81 0.00 – 1.24 (2.48)	3.06 0.54 – 6.60 (13.18)	23.00 – 26.20	38.26 – 59.03
2005/2006	Advertisement	16.74 0.52 – 50.43	7.40 0.00 – 24.66	10.15 1.19 – 31.01	1.01 0.00 – 4.73	10.13 0.53 – 34.07	18.40 – 30.00	28.23 – 54.91

		(24.34)	(14.21)	(20.95)	(3.93)	(15.74)		
		14.88	13.36	15.45	0.69	6.48		
	Aggressive	5.34 – 57.54 (21.66)	0.00 – 28.28 (20.30)	3.74 – 28.12 (16.31)	0.00 – 2.16 (2.57)	1.43 – 31.90 (8.33)	18.70 – 30.00	32.71 – 54.91
Reproductive season	Call type	Call duration	Number of pulses	Pulse duration	Dominant frequency	Pulse repetition rate	Temperature (°C) Range	Body size range
2006/2007	Advertisement	16.63 0.80 – 44.17 (19.96)	9.27 0.00 – 22.92 (10.03)	8.88 2.09 – 25.62 (35.35)	0.93 0.00 – 2.54 (4.05)	9.81 0.79 – 23.95 (15.11)	18.20 – 30.70	36.07 – 62.92
	Aggressive	16.09 4.12 – 44.72 (19.70)	14.68 0.00 – 31.85 (24.92)	14.67 3.11 – 47.78 (29.55)	0.94 0.00 – 4.61 (4.11)	9.01 1.81 – 43.44 (11.80)	18.20 – 30.70	36.07 – 61.52
2007/2008	Advertisement	27.02 3.31 – 56.04 (34.19)	11.50 0.00 – 30.12 (17.79)	11.09 3.95 – 26.42 (17.52)	0.96 0.00 – 2.22 (5.17)	13.10 3.23 – 23.84 (20.31)	21.00 – 26.20	27.61 – 64.00
	Aggressive	13.35 6.33 – 31.62 (14.14)	16.80 7.21 – 34.48 (15.68)	16.52 3.71 – 62.66 (21.76)	0.87 0.00 – 1.54 (4.47)	6.58 1.54 – 21.53 (8.28)	21.00 – 26.20	27.61 – 64.00
2008/2009	Advertisement	16.43 1.03 – 48.42 (19.11)	7.88 0.00 – 22.36 (12.19)	9.45 1.83 – 24.74 (19.96)	0.85 0.00 – 2.51 (3.47)	8.22 1.04 – 24.59 (15.31)	13.1 – 25.6	31.04 – 54.53
	Aggressive	14.93 5.88 – 33.89 (16.14)	17.73 9.32 – 28.56 (14.12)	15.10 5.18 – 28.56 (19.01)	0.75 0.00 – 1.55 (4.03)	7.49 1.78 – 16.16 (8.10)	13.1 – 25.6	31.04 – 52.59
2011/2012	Advertisement	19.98 1.01 – 44.92 (32.35)	8.92 0.00 – 22.81 (18.44)	9.47 2.54 – 17.57 (17.24)	0.48 0.00 – 2.91 (2.26)	9.83 1.02 – 20.46 (17.86)	18.78 – 23.71	37.79 – 52.71
	Aggressive	-	-	-	-	-	-	-

Reproductive season	Call type	Call duration	Number of pulses	Pulse duration	Dominant frequency	Pulse repetition rate	Temperature (°C) Range	Body size range
2012/2013	Advertisement	16.21 1.32 – 55.69 (27.66)	7.24 0.00 – 23.30 (15.23)	7.48 2.32 – 17.41 (10.50)	1.05 0.00 – 3.14 (3.12)	10.46 1.29 – 29.63 (17.21)	21.10 – 26.31	32.89 – 60.87
	Aggressive	13.37 0.44 – 43.37 (19.16)	14.95 0.00 – 35.37 (21.19)	14.76 3.33 – 37.68 (25.60)	1.01 0.00 – 4.33 (2.63)	6.66 0.43 – 17.07 (12.90)	21.10 – 26.31	32.89 – 60.87
2013/2014	Advertisement	17.99 2.81 – 41.61 (14.24)	11.16 0.00 – 21.16 (9.24)	12.71 6.12 – 21.43 (21.28)	1.12 0.00 – 3.30 (2.44)	12.07 2.70 – 28.14 (10.26)	19.1 – 23.90	32.44 – 51.54
	Aggressive	10.24 3.05 – 17.35 (10.26)	14.53 9.31 – 28.85 (14.15)	19.13 13.13 – 37.29 (29.40)	1.80 0.00 – 3.31 (2.06)	6.96 2.29 – 13.75 (10.81)	19.1 – 23.90	32.44 – 51.54

	Advertisement	17.91 0.52 – 56.04 (25.25)	9.00 0.00 – 30.12 (14.14)	9.00 1.19 – 31.01 (18.77)	0.95 0.00 – 4.98 (3.32)	10.30 0.53 – 34.07 (16.39)	13.1 – 30.7	27.61 – 65.02
Total								
	Aggressive	13.53 0.44 – 57.54 (16.27)	14.30 0.00 – 35.37 (17.43)	14.50 3.11 – 62.66 (21.80)	0.98 0.00 – 4.61 (3.09)	6.42 0.43 – 43.44 (10.13)	13.1 – 30.7	27.61 – 64.00

The reproductive season 2011/2012 was withdrawn from these analyses because of the low number of individuals (3) and aggressive calls (13).

Table S6. Multiple linear regressions for the advertisement and aggressive calls of *B. goiana* between 1996 and 2014 with importance for selection in multi-model inference, partial regression coefficients, unconditional variance and confidence interval of predictor variables. Values in bold are variables considered for having importance above 0.8. Response variables: CD = call duration; NP = number of pulses; PD = pulse duration; DF = dominant frequency; CRR = call repetition rate; PRR = pulse repetition rate.

Call Type	Variables	Importance	Partial regression coefficients	Unconditional Variation	Confidence Interval
	CD				
	Body Size	0.2611	<0.0001	<0.0001	0.0005
	Year	0.2932	0.0003	<0.0001	0.0013
Advertisement	Temperature	0.3393	0.0008	<0.0001	0.0032
	NP				
	Body Size	0.2761	-0.0004	<0.0001	0.0030
	Year	0.4320	0.0039	<0.0001	0.0120
	Temperature	0.6124	0.0142	0.0002	0.0303
	PD				

	Body Size	0.8402	0.0001	<0.0001	0.0002
	Year	0.9996	-0.0006	<0.0001	0.0003
	Temperature	0.2889	0.0000	<0.0001	0.0002
DF					
	Body Size	1.0000	-6.6699	1.4418	2.3703
	Year	0.6664	2.5661	6.1524	4.8964
	Temperature	0.5092	-2.7817	13.6988	7.3063

Call Type	Variables	Importance	Partial regression coefficients	Unconditional Variation	Confidence Interval
	CRR				
	Body Size	0.2921	0.0032	0.0001	0.0167
	Year	0.2685	0.0027	0.0001	0.0226
Advertisement	Temperature	0.5881	0.0617	0.0049	0.1388
	PRR				
	Body Size	0.2795	-0.0021	<0.0001	0.0131
	Year	0.2866	0.0044	0.0002	0.0246
	Temperature	0.2957	-0.0097	0.0006	0.0488
	CD				
Aggressive	Body Size	0.4014	0.0003	<0.0001	0.0009
	Year	0.6258	-0.0011	<0.0001	0.0023
	Temperature	0.2771	0.0002	<0.0001	0.0014

	NP				
	Body Size	0.3372	0.0033	<0.0001	0.0130
	Year	0.2929	-0.0033	0.0001	0.0169
	Temperature	0.2673	0.0030	0.0001	0.0234
	PD				
	Body Size	0.7141	0.0001	<0.0001	0.0001
	Year	0.9913	-0.0003	<0.0001	0.0002
	Temperature	0.3680	0.0001	<0.0001	0.0002

Call Type	Variables	Importance	Partial regression coefficients	Unconditional Variation	Confidence Interval
	DF				
	Body Size	0.9998	-5.6760	1.5870	2.4936
	Year	0.4220	1.1165	3.1174	3.4949
	Temperature	0.3707	-1.4711	6.8922	5.1965
Aggressive	CRR				
	Body Size	0.2819	0.0070	0.0004	0.0386
	Year	0.9994	-0.3401	0.0065	0.1601
	Temperature	0.2558	-0.0031	0.0016	0.0786
	PRR				

Body Size	0.2740	-0.0028	0.0001	0.0195
Year	0.6425	0.0532	0.0029	0.1070
Temperature	0.2565	-0.0010	0.0005	0.0438

Figure S1. Localization in Brazilian territory (above) and satellite image (bellow) of Silvânia National Forest. The black dot represents the recording location of *B. goiana* between 1996 and 2014 ($16^{\circ}38'19,65''S$; $48^{\circ}38'55,40''W$).

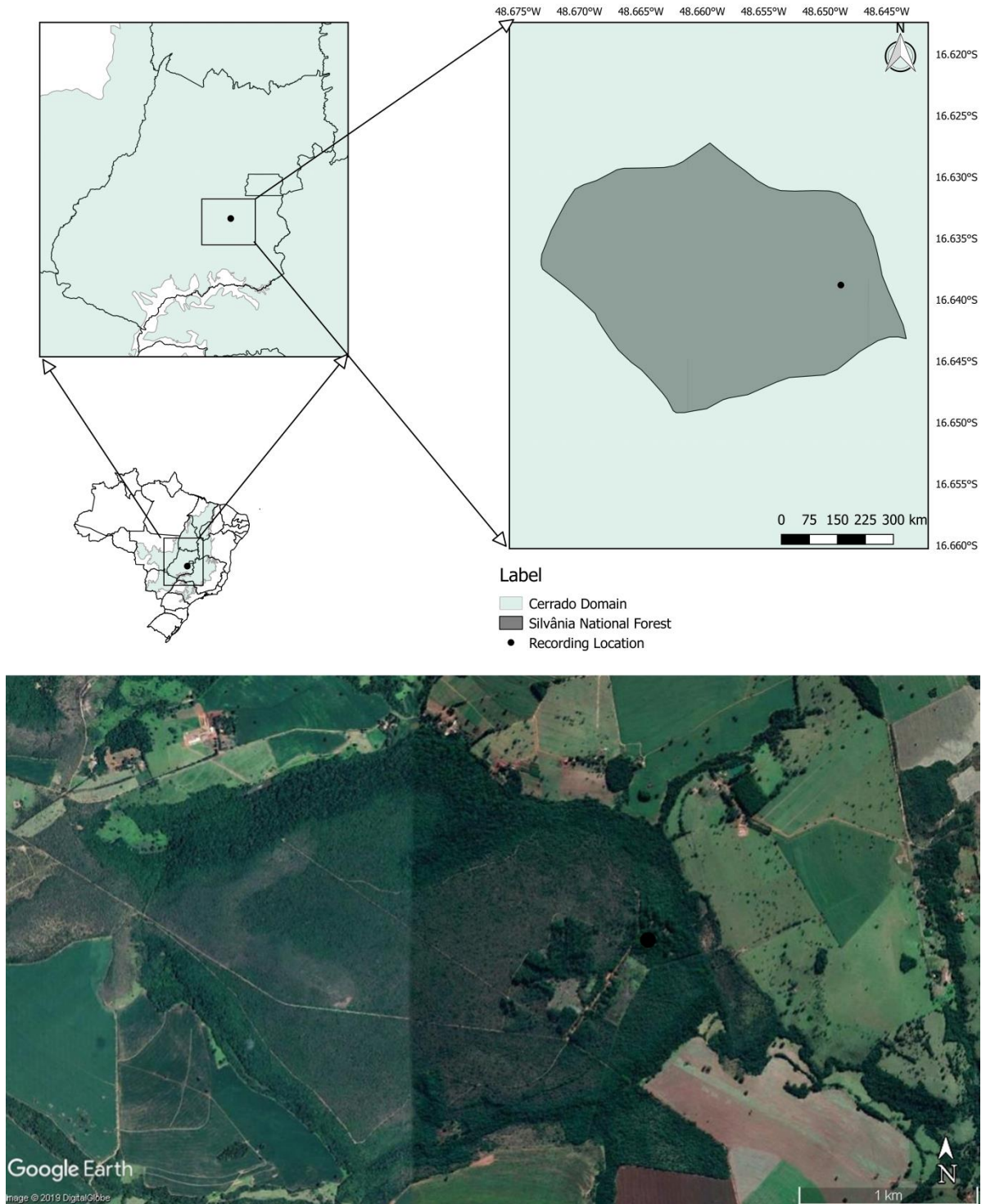


Figure S2. Intra-individual variation coefficients for the acoustic parameters of advertisement calls of *B. goiana*, recorded in ten reproductive seasons (between 1996 and 2014) in the Silvânia National Forest, municipality of Silvânia, Goiás State, Brazil. The solid line indicates the 5% variation threshold, while the dashed line indicates the 12% threshold. The dotted line represents the average variation considering all individuals analysed during the 18 years of sampling.

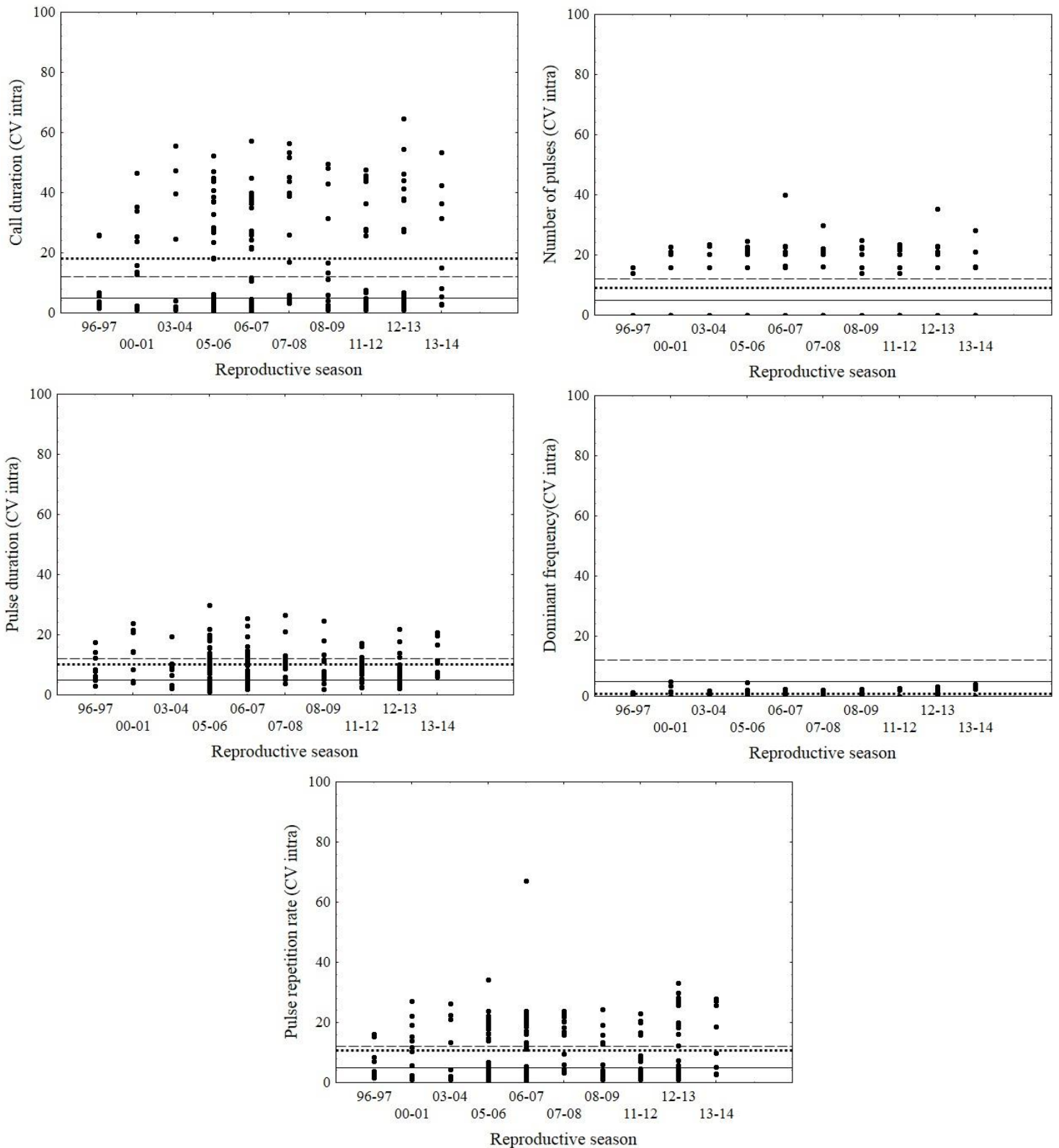


Figure S3. Intra-individual variation coefficients for the acoustic parameters of aggressive calls of *B. goiana*, recorded in ten reproductive seasons (between 1996 and 2014) in the Silvânia National Forest, municipality of Silvânia, Goiás State, Brazil. The solid line indicates the 5% variation threshold, while the dashed line indicates the 12% threshold. The dotted line represents the average variation considering all individuals analysed during the 18 years of sampling.

