

INDIVIDUAL ACOUSTIC IDENTIFICATION AS A NON-INVASIVE CONSERVATION TOOL: AN APPROACH TO THE CONSERVATION OF THE AFRICAN WILD DOG *LYCAON PICTUS* (TEMMINCK, 1820)

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ABSTRACT

Individual variation in acoustic signals can be used for discrimination or identification purposes as a valuable supplement to radio-tagging and visual recognition. In this study, 721 *hoo-calls* from captive and free-ranging African wild dogs *Lycaon pictus* ($n=9$) were investigated for individual acoustic cues. The investigation applied a computer-aided sound analysis that allowed measurement of 93 parameters for each *hoo-call*. Discriminant function analyses demonstrated that the individuals differed in their call parameters primarily measured on the fundamental frequency. Additional discriminant analyses were run in order to find out if individuals can be re-identified once their *hoo-calls* are recorded and catalogued into a voice library. This procedure yielded an overall 67% correct assignment for the test data (ranging from 37% to 98% per individual), suggesting an above chance level re-recognition of individuals. The results establish the capability of re-identifying wild dogs using specific acoustic characteristics of their *hoo-call*, and suggest that this technique can be a useful tool in conserving this highly endangered species.

Keywords: *Lycaon pictus*, canids, individual acoustic distinctiveness, multiparametric sound analysis, voice library

INTRODUCTION

Individual distinctiveness is necessary for discriminatory and re-identification of animals in a study population. The ability to reliably identify individual animals is critical in order to gain detailed ecological data of a study population, and makes conservation efforts more effective (see Baptista & Gaunt 1997; McGregor & Peake 1998; McGregor et al. 2000). For example, census and survey activities rely on individual recognition of the study animals. Population dynamics can only be understood if dispersal patterns and social structures are investigated, and this again is based on the ability to identify each individual.

The identification of African wild dogs *Lycaon pictus* through photographic records (Maddock & Mills 1994) is well established, but it is not suitable in dense vegetation or over long distances. Individuals that are out of sight can currently only be identified using radio-telemetry. However, it is not financially practical to radio-collar every individual. Besides that, collaring is typically an invasive procedure that involves capturing and immobilising animals with anaesthetic darts, which can cause mild to lethal injuries (see Creel & Creel 2002; pers. com Rasmussen). Further, it has been suggested that these procedures may induce stress in African wild dogs (de Villiers et al. 1995), and is associated with the mortality in the Serengeti-Mara-population (Burrows et al. 1995).

Individual recognition by acoustic signals, a non-invasive identification method (see McGregor et al. 2000; Terry et al. 2001) was tested on wild dogs because it is likely to work when animals are in dense vegetation. As a prerequisite for acoustic re-identification, vocal utterances were investigated for individual characteristics. Individually distinctive acoustic features have been demonstrated in a large number of birds (e.g. Falls 1982) and mammals (e.g. Marler & Hobbett 1975; Lillehei & Snowdon 1978; Symmes et al. 1979; Hammerschmidt & Todt 1995; Riede 1997; Rendell et al. 1999). Within canids the presence of vocal signatures has been shown in wolves *Canis lupus* (Tooze et al. 1990), Arctic foxes *Alopex lagopus* (Frommolt et al. 2003), dholes *Cuon alpinus* (Durbin 1998), and swift foxes *Vulpes velox* (Darden et al. 2003). In *Lycaon pictus*, no data showing individually specific characteristics in vocalisations are available. The investigation of individually specific acoustic characteristics focused on the only known long distance call of *Lycaon*, a tonal sound that is commonly known as the *hoo-call* or *hoot*. *Hoo-calls* are emitted repeatedly in a long series (bout) of homogenous calls (up to 30 or more) with an interval period of 400 to 850 ms. They are usually uttered in the context of isolation or separation in order to locate other pack members for reunion (Marten 1980; Robbins 2000; Creel 2002). African wild dogs can *hoo-call* while standing, walking or lying with the head lowered to the ground.

The aim of the present study was to find parameters in the *hoo-call* that encode acoustic identity in African wild dogs, and to test a method of acoustically re-identifying each member of the population with a high probability.

MATERIAL AND METHODS

Study animals and study sites

The sound recordings were collected in Zimbabwe and at the Safari

Park Beekse Bergen in the Netherlands (Table 1). In Zimbabwe, acoustic data were obtained from a free-ranging pack (Gwayi Valley Conservancy) and a wild caught pack, that was initially kept in an enclosure (Fothergill Island, Matusadona National Park) during a translocation project (Hartwig & Rasmussen 1999). All *hoo-calls* submitted to the acoustic analyses were uttered by adult animals (3 to 5 years old) that were isolated (separated) from other pack members. The free-ranging study animals vocalized when they lost contact with their pack members while hunting. The wild pack kept in the boma started *hoo-calling* when some pack members escaped from the enclosure. In the Safari Park Beekse Bergen, single animals (all captive bred) were experimentally separated from the pack for 20 minutes in order to evoke a bout of *hoo-calls*.

Vocal recordings and sound analysis

Vocalisations were recorded *ad libitum* using a Sony Professional WM D6C cassette recorder and a Sennheiser ME 67 directional microphone with a frequency response of 50-20000 Hz \pm 2.5 dB. The distance between the subject and the microphone ranged between 20 and 50 m. The recordings in Zimbabwe and in the Safari Park were made in forested and woodland habitats.

In total, 1203 *hoo-calls* were recorded from 12 adult individuals ($n=774$) and 3 puppies ($n=429$). I selected 721 calls from different vocalisation bouts of 9 adult individuals for the acoustic analyses.

TABLE 1.

Data sources and sample sizes for the acoustic analyses. The sound recordings in Beekse Bergen were collected in 1995, 2000 and 2001, in Matusadona National Park from July to September 1997, and in Gwayi Valley conservancy in 1998 and 1999. The animals at each location were closely related to one another.

individual	sex	location of recording	<i>n</i> of calls	<i>n</i> of series = bouts
1	f	Safari Park Beekse Bergen (Netherlands)	142	9
2	f	Safari Park Beekse Bergen (Netherlands)	64	6
3	f	Safari Park Beekse Bergen (Netherlands)	201	11
6	m	Safari Park Beekse Bergen (Netherlands)	56	6
7	m	Safari Park Beekse Bergen (Netherlands)	30	4
4	m	Matusadona National Park (Zimbabwe)	160	11
5	m	Matusadona National Park (Zimbabwe)	39	6
8	f	Gwayi Valley Conservancy (Zimbabwe)	11	2
9	m	Gwayi Valley Conservancy (Zimbabwe)	18	2
total			721	57

Sound recordings were excluded if the quality was poor (excessive background noise) or if calls of different individuals overlapped.

The calls were digitised with a 40-kHz sample rate using the real-time sound analysis program AVISOFT-SASLab Pro Version 4.23b for Microsoft-Windows. A Fast Fourier Transformation (FFT) was conducted using a Hamming window (256-pt FFT). A custom software package (LMA 8.0) that extracts different sets of call parameters from acoustic signals was used to analyse the frequency-time spectra (see Schrader & Hammerschmidt 1997). Specific sets of parameters were calculated that describe the signal structures. The first set of parameters measured the statistical distribution of the frequency amplitudes in the spectrum (dfa parameters). For each time segment, the overall amplitude was determined. A second set of parameters calculated the first three dominant frequency bands, which are equivalent to the harmonics in tonal sounds (dfb parameters). Additional to the mean and maximum values for these structural parameters, the local and global modulation of modulation of the 1st dfb for the entire call was estimated. A further set of parameters described their formant like structures (fls) and represented the frequency ranges with highest energy within the spectrum. Another set of parameters specified the modulation of the peak frequency, the frequency with the highest amplitude (peak frequency = pf parameter) in a certain time segment. The last set of parameters (consistence parameters = cs parameters) calculated the correlation values of the power spectra of successive time segments. The time course of these correlation values can be used to detect points of changes in a vocalisation.

A detailed description of the calculation of parameters and the filtering algorithms that correct for varying distances between sender and microphone is given in Schrader & Hammerschmidt (1997).

Statistical analysis

The statistical analysis was performed using the program package SAS version 8.2. A stepwise discriminant analysis (PROC STEPDISC) was applied to reduce the number of variables by excluding those that were highly correlated in order to determine the acoustic parameters that were important to discriminate the individuals.

In total, 93 discrete variables were extracted from digitised frequency-time spectra but only 31 variables remained after the stepwise discriminant analysis. However, in the final discriminant function analysis, only variables that exhibited greater between individual variation than within individual variation were used. The selection procedure resulted in 22 variables (see Appendix) that were used to run the discriminant analyses (PROC DISCRIM) in order to test the accuracy of individual identification.

The call set of each individual was randomly (from each call bout) split into approximately equal-sized sub sets. One of these two sub sets (the training set) was used to establish the set of discriminant functions. The other sub set (the test set) was scored according to these functions in order to see if the calls are correctly assigned. For illustration, an additional factor analysis was run to summarise the correlating variables.

The NPAR1Way procedure of SAS (Wilcoxon-test) was used to investigate for possible effects of sex and population differences in zoo and wild animals (recording conditions). The effects of age were not considered because the study animals were approximately of the same age group.

RESULTS

In some cases, the fundamental frequency structure of the *hoo-calls* from different animals were visually distinguishable in the spectrograms when compared (Figure 1). It was even more noticeable if two or more individuals vocalised at one time (Figure 2). The fundamental frequency of adult *hoo-calls* was between 440 and 680 Hz, and occasionally included one or two overtones (harmonics or multiples of the fundamental frequency). The duration of the *hoo-call* ranged between 250 to 450 ms, but did not contribute to a reliable discrimination between the individuals. Acoustic characteristics that were useful for discriminating individuals primarily included fundamental frequency parameters such as start and mean.

However, only the multiparametric statistical analysis (see Backhaus et al. 1993) of the calls verified the differences between the individuals. Table 2 shows the differences of 22 call parameters for 9 individuals.

The discriminant function analysis assigned 77% (average) of each *hoo-call* (n=721) to its correct group (individual). However, the correct assignments are overestimated because the data sets tested were the same data sets run in the discriminant analysis. Because of this confound, the data sets were split into a training set and test set for each individual. The proportion of test calls that were correctly assigned ranged from 37%-98% (see Table 3) when using the selected 22 variables, indicating that half or more of the test calls were correctly recognised. Even in cases when only 37% were correctly assigned, the result was still highly suggestive because the chance level of a correct assignment among 9 individuals using a randomisation process is only 11.1%. The scattergram illustrates the distribution of the first two factors obtained from 22 variables from a factor analysis (Figure 3). The two factors together describe 58% of the variations. Parameters that correlate with the two factors are listed in Table 4.

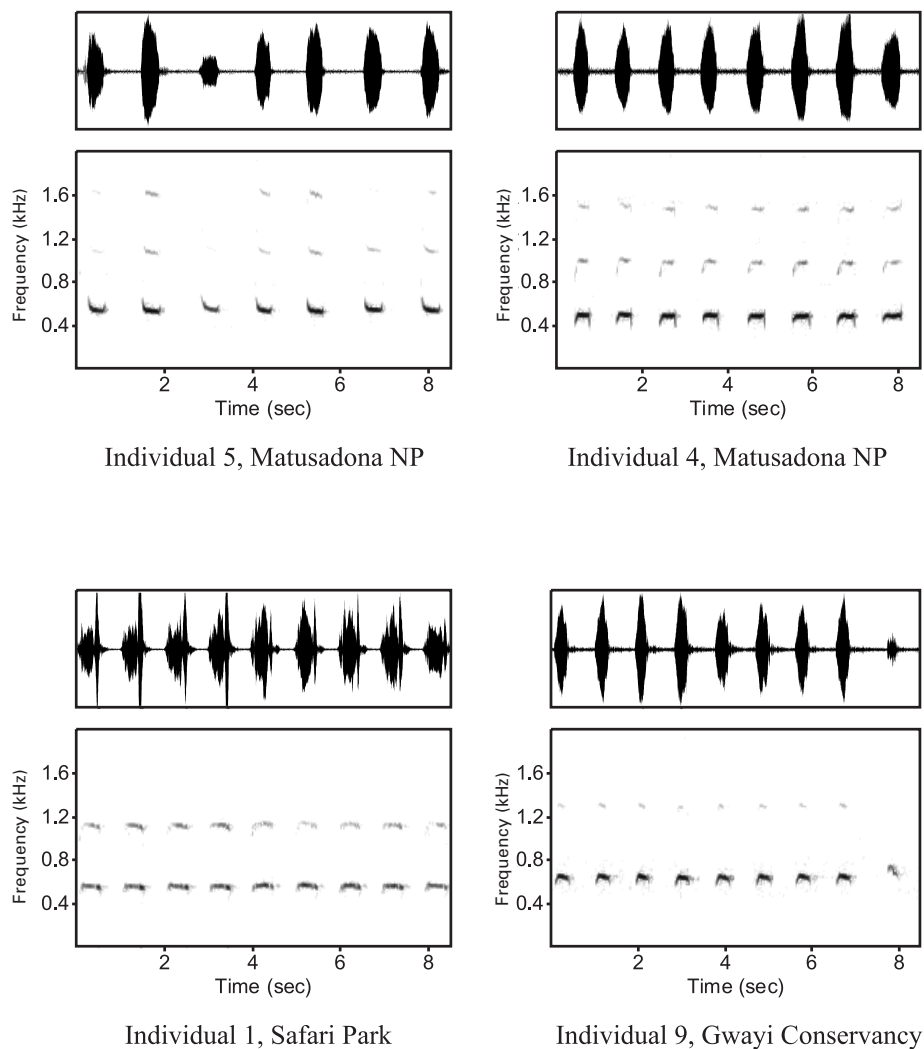


Figure 1. Spectrograms of *hoo-call* series from 4 different individuals. In these spectrograms the physical structure of single *hoo-calls* is visually distinguishable. The fundamental frequencies, call lengths, and inter-call intervals are clearly different for each individual.

The variables that were used showed greater between individual variation than within individual variation (univariate analysis of variance, p -values < 0.0001), which suggests that the individuals were discriminated and not the calls. Because the calls were selected from different bouts (temporally spaced) of each individual, it can be assumed that the samples were independent.

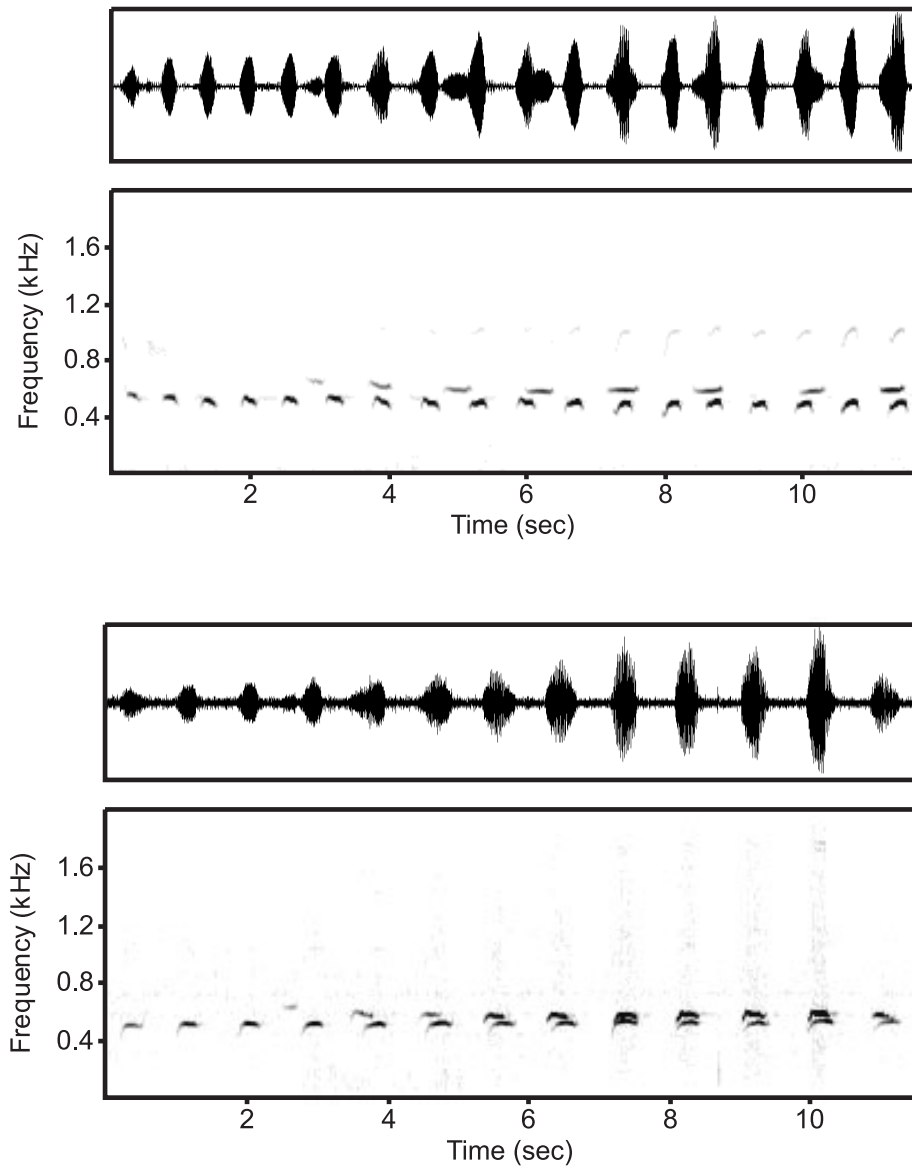


Figure 2. The spectrograms show concurrent vocalisations from individuals in two different groups. In the first spectrogram the individuals differ clearly in fundamental frequency parameters such as start and maximum frequency. The call lengths and intervals between the calls also show clear differences, whereas the second spectrogram shows individuals whose vocalisation characteristics are much more similar.

TABLE 2
 Summary statistics results for the total sample (721 calls, 9 individuals) of 1-Way-ANOVA (R^2) for the selected variables ($p < 0.0001$).

Variable	Individual									
	1	2	3	4	5	6	7	8	9	
q1end	Mean	547	605	664	486	523	512	456	556	670
	Std Dev	28	56	13	18	36	26	37	17	54
2st	Mean	648	897	960	532	608	495	650	804	950
	Std Dev	120	145	166	78	93	131	101	64	65
q2max	Mean	658	933	1095	561	631	704	710	882	980
	Std Dev	116	157	160	91	103	134	118	22	52
q2mean	Mean	601	831	901	521	595	605	604	798	893
	Std Dev	20	129	94	40	54	73	75	31	88
q2med	Mean	590	815	899	510	585	591	586	775	874
	Std Dev	18	142	127	40	58	84	74	39	91
q3max	Mean	956	1277	1403	862	942	1084	1046	1241	1331
	Std Dev	149	165	20	149	221	118	97	21	45
q3med	Mean	747	1164	1372	700	782	974	951	1175	1263
	Std Dev	173	206	19	176	204	106	93	14	59
df1chfre	Mean	44	44	28	62	44	35	52	58	42
	Std Dev	18	16	10	20	15	15	18	5	17
df1chmax	Mean	30	137	19	2.9	31	51	51	43	6.7
	Std Dev	46	133	34	2	43	57	45	43	6.5
df1miloc	Mean	0.25	0.39	0.5	0.08	0.3	0.4	0.5	0.2	0.4
	Std Dev	0.3	0.4	0.4	0.2	0.3	0.3	0.4	0.3	0.4

df1mtr	Mean	10	51	7	3	12	19	21	15	6
	Std Dev	11	41	8	2	16	20	24	15	4
df1maxtr	Mean	54	210	36	11	55	79	81	83	15
	Std Dev	67	179	50	6	69	88	81	72	7
df3mean	Mean	459	867	763	132	192	571	557	907	662
	Std Dev	499	484	692	375	397	490	434	190	582
df4pr	Mean	0.8	15	1	0.06	0.3	2.7	0.5	8.5	10
	Std Dev	2.5	18	3	0.6	1.2	6	1.7	8.9	17
dffremax	Mean	2.5	5	3	2	1.9	3	2.7	8.5	6
	Std Dev	0.9	2.7	1	0.7	0.9	1	0.6	6.3	5
flwst	Mean	160	234	170	154	165	194	183	708	542
	Std Dev	52	197	48	28	45	99	42	491	451
flwmax	Mean	171	336	185	167	186	234	224	805	566
	Std Dev	47	270	49	26	54	80	46	454	482
f3pr	Mean	0.11	16	0.9	0.02	0.1	1.8	0.3	6.5	4
	Std Dev	0.77	18	3	0.2	0.5	5	1.6	4.5	5
pfst	Mean	625	778	887	485	557	536	489	532	632
	Std Dev	117	321	317	22	20	49	113	34	214
pfmax	Mean	639	914	1113	505	574	579	581	540	742
	Std Dev	117	354	345	22	11	136	167	28	352
esmaxd	Mean	0.0002	0.002	0.0008	0.0001	0.0003	0.0007	0.001	0.007	0.001
	Std Dev	0.0004	0.001	0.0009	0.0003	0.0005	0.0009	0.001	0.003	0.001
esmaloc	Mean	0.3	0.4	0.4	0.3	0.5	0.4	0.5	0.8	0.6
	Std Dev	0.3	0.4	0.4	0.3	0.4	0.3	0.4	0.4	0.4

TABLE 3

Results of the discriminant analyses in which each individual's data set was split into a training set and a test set.

individual	total call set	training set	correct assignment of the training set %	test set	correct assignment of the test set %
1	142	71	80.3	71	52.1
2	64	32	59.4	32	53.1
3	201	91	100	110	98.2
4	160	81	76.5	79	76
5	39	21	71.5	18	42.2
6	56	29	69	27	37
7	30	13	69.2	17	82.3
8	11	5	80	6	66.7
9	18	9	88.4	9	88.9
total	721		77.1		66.8

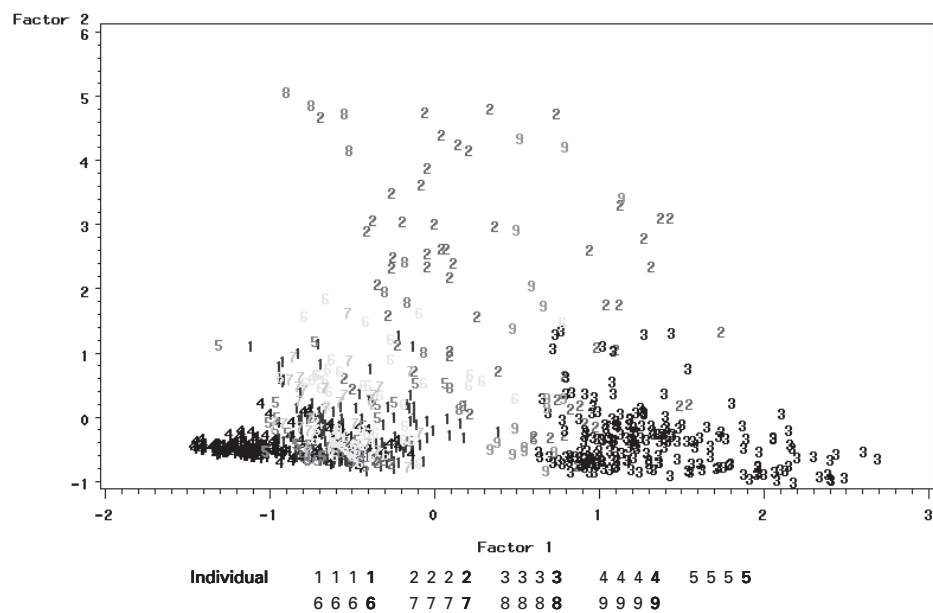


Figure 3. Scattergram to demonstrate the distinctiveness of each individual's calls. Factor 1 and 2 are the first two discriminant functions obtained from the whole data set (n=721).

TABLE 4

Parameters that showed the highest correlation with the discriminant functions established to discriminate between individuals.

	Rotated Factor Pattern	
	Factor 1	Factor 2
q1end	0.86957	0.07958
q2st	0.89100	0.22846
q2max	0.94007	0.17063
q2mean	0.94167	0.23227
q2med	0.91829	0.21092
q3max	0.88156	0.22301
q3med	0.89077	0.20513
df1chfre	-0.51369	0.01822
pfst	0.74229	0.02832
pfmax	0.81243	0.12499
df1chmax	0.07938	0.66700
df1mtr	0.05320	0.73712
df1maxtr	0.07727	0.69555
df4pr	0.05755	0.81858
dffremax	0.19340	0.83907
f1wst	0.00998	0.63405
f1wmax	0.01268	0.76990
f3pr	0.07987	0.72092
csmaxd	0.20300	0.58413

Additionally a Wilcoxon Two-Sample Test was applied to test for possible gender and population differences. The results showed that there were differences between zoo- and wild animals but less than between the males and the females (p-values < 0.0001).

DISCUSSION

The analyses demonstrate that wild dogs can be identified on the basis of their *hoo-calls* only. The *hoo-call* offered a sufficiently high amount of variation to ensure the acoustic discrimination of nine study animals, although gender and population possibly affected vocal individuality as well, but could not be verified due to the small sample size of the groups.

Furthermore, it has not been tested to what degree individual acoustic signatures in *hoo-calls* persist over time. This has been shown to occur in isolation peeps of squirrel monkeys *Saimiri sciureus* (Symmes et al. 1979), in whoops of spotted hyenas *Crocuta crocuta* (East & Hofer 1991) and in booms of European bitterns *Botaurus stellaris* (Gilbert et al. 1994).

Although the recordings were taken at temporally spaced intervals (see Table 1), the intra-individual variation (within the individuals calls) did not change ($p > 0.05$), which indicates that *hoo-calls* remain individually stable. The sound analyses of Wilden (1997) over a two-year time period also support these results and suggest a sufficient consistency in acoustic parameters by early adulthood.

The fundamental frequency of vocal utterances and their overtones are largely determined by characteristics of an individual's vocal apparatus, such as sound source characteristics (respiratory activity, vocal folds within the larynx), and its vocal tract length, i.e. the supralaryngeal space filtering the primary source signal (Michelson 1983; Hauser 1991; Tembrock 1996). These factors are probably relatively constant in adult wild dogs, and therefore contribute to a reliable discrimination between individuals over several years. However, no detailed anatomical data on this question have been collected for *Lycaon pictus*.

Individual characteristics in signal structures can be degraded during transmission through the atmosphere and will inhibit long-distance identification of an individual. According to Wiley and Richards (1978) frequency modulation in tonal signals and the repetition of sound pulses counteracts such degradations. Stereotypy may also facilitate the detection and recognition of *hoo-calls* broadcast over long distances in dense vegetation, as with *pant hoots* in chimpanzees (see Marler & Hobbett 1975; Mitani et al. 1996). Moreover, sound transmission is less susceptible to the variability of vertical temperature and wind gradients in forested than in more open habitats (Morton 1975). Therefore it is likely that acoustic features in the *hoo-call* that encode the signaller's identity are transmitted better in forested habitats.

Hoo-calls are the most suitable of *Lycaon's* vocalisations for an acoustic survey technique because they are loud, repetitive and are recordable over long distances. Nevertheless, it should be taken into consideration that it takes some time to collect a call sample from free-ranging wild dogs that is large enough to run a reliable discriminant analysis: this limits the application of this method.

Therefore it is suggested that the identification of free-ranging wild dogs by the *hoo-call* is mainly used in addition to radio-collaring or to photographic reference collections. However, it might be particularly useful for future re-introduction programs that aim to build up metapopulations. An example is the Wild Dog Action Group of South Africa (WAG-SA), which is planning to set up a viable number of subpopulations (a metapopulation) in South Africa by introducing wild *Lycaon* packs into several small reserves (Mills et. al 1998). Before introducing wild dog packs into the new habitat, they could be held in an enclosure, where *hoo-calls* are easier to collect (see Hartwig & Rasmussen 1999). They can be triggered by playback

recordings and by means of isolation experiments (Hartwig in prep.). The calls could be stored in a “voice archive” (see Seymour & Titze 1989; Ranft 1997) and compared to recordings made after the release, which would help to re-identify individuals that were not visually identified. The archival recordings both of wild and zoo animals could also be used as a database of the *Lycaon* specific vocal repertoire for future acoustic analyses and thus could provide useful information for wild dog conservation.

This computer-aided acoustic analysis, with its reliable calculation of sound representation such as power spectra free from observer bias, and its rapid automated calculation of multiple parameters is suitable for discriminatory and re-identification procedures. Further, it takes into account different sound production and recording conditions. This method allows a researcher to acquire data from individuals that are out of sight and not wearing radio-collars, which usually give the carrier's identity (via frequency) and information about its activity movements. Acoustic identification could be established as a supplemental technique to photo identification and the use of telemetry. The costs of acoustic monitoring is minimal and most importantly, it has no deleterious effects on the study animals, making it well suited for conservation-orientated *Lycaon* research.

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APPENDIX

Acoustic parameters used in the analysis. The parameters were calculated from the original frequency-time spectra.

parameters	description
q1end [Hz]	end of the 1 st quartile of distribution of frequency amplitudes (dfa)
q2st [Hz]	start of the 2 nd quartile of distribution of frequency amplitudes (dfa)
q2max [Hz]	max of the 2 nd quartile of distribution of frequency amplitudes (dfa)
q2mean [Hz]	mean of the 2 nd quartile of distribution of frequency amplitudes (dfa)
q2med [Hz]	median of the 2 nd quartile of distribution of frequency amplitudes (dfa)
q3max [Hz]	max of the 3 rd quartile of distribution of frequency amplitudes (dfa)
q3med [Hz]	median of the 3 rd quartile of distribution of frequency amplitudes (dfa)
df1chfre	local modulation of frequency difference of the 1 st dominant frequency band (dfb)
df1chmax	local modulation of maximum difference of the 1 st dominant frequency band (dfb)
df1miloc [Hz]	location of the minimum frequency of the 1 st dominant frequency band (dfb)
df1mtr	global modulation of change; mean difference between trend and original curve of the 1 st dominant frequency band (dfb)
df1maxtr	global modulation of change; maximum difference between trend and original curve of the 1 st dominant frequency band (dfb)
df3mean [Hz]	mean of the 3 rd dominant frequency band (dfb)
df4pr [%]	percentage of time segment in which a 4 th dominant frequency band (dfb) could be found
dffremax	total number of the dominant frequency band in a spectrum at maximum (dfb)
f1wst [Hz]	range of the 1 st formant-like structure (fls) at start
f1wmax [Hz]	range of the 1 st formant-like structure (fls) at maximum
f3pr [%]	percentage of time segments in which a 3 rd fls could be found
pfst [Hz]	start frequency of peak amplitude (pf parameter)
pfmax [Hz]	maximum frequency of peak amplitude (pf parameter)
csmaxd	maximum change in the time course of the correlation values (cs parameter)
csmaloc	location of the maximum change in the time course (cs parameter)
