

Short Note

Morphometrics of Pampas foxes (*Pseudalopex gymnocercus*) in the Argentine Pampas

Estela Luengos Vidal^{1,*}, Mauro Lucherini^{1,2},
Emma Casanave^{1,2} and Claudio Sillero-Zubiri³

¹ GECM – Cát. Fisiología Animal, Departamento de Biología, Bioquímica y Farmacia, Universidad Nacional del Sur, San Juan 670, B8000CPB Bahía Blanca, Argentina, e-mail: eluengos@criba.edu.ar

² CONICET – Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina

³ Wildlife Conservation Research Unit, University of Oxford, Tubney House, Abingdon Road, Tubney OX13 5QL, UK

*Corresponding author

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The size of a mammal is closely related to and influences virtually every aspect of its biology (McNab 1971, Clutton-Brock and Harvey 1983) from its physiology and behaviour to its life history and ecology (Gehrt and Fritzell 1999). Total mammalian body mass may indicate the condition of individuals (Sweitzer and Berger 1993) and the mean body mass across individuals may indicate the health of a population (Harder and Kirkpatrick 1994, Warlick and Cypher 1999). Therefore, morphological information may be particularly valuable when managing populations. Sexual dimorphism is a frequent source of intra-specific variability, and it should be taken into consideration in population studies. Moderate sexual dimorphism is common among canids, with females on average 3%–4% smaller in linear measurements than males (Hildebrand 1953).

The Pampas fox, *Pseudalopex gymnocercus* (Fisher, 1914), inhabits grasslands and open woodlands of the Southern Cone of South America, where it is one of the most common and widespread carnivorous species (Lucherini et al. 2004). The taxonomic status of *P. gymnocercus*, and other congeners, is somewhat controversial (Massoia 1982, Zunino et al. 1995) and morphological data are scant (Barlow 1965, Crespo 1971, Massoia 1982, Mares et al. 1989, Craviño et al. 1999, Lucherini et al. 2004). Of previously published data, only Crespo (1971) presents a good sample of detailed measurements (from Espinal open woodland in La Pampa Province). Furthermore, the few data that exist were rarely collected in a standardized manner. The use of a standardized measurement protocol on a large sample size should provide valuable information on morphology,

body condition and sexual dimorphism, and provide a basis for comparison with other studies.

In this paper, we present data on morphology and sexual dimorphism of the Pampas fox and compare our results to those from other studies. Body mass was investigated in relation to age, sex, season and year. Additionally, we sought to validate the age classification used in the field through comparison with other traits and investigated alternative field-measurable traits for future field work.

Pampas foxes were captured in the south-east of Buenos Aires Province between 1999 and 2005 in two localities (Parque Provincial Ernesto Tornquist 38°04'00S–62°04'00W and Estancia San Mateo, 38°39'00S–60°59'00W). These two areas are less than 100 km apart and are located in the transition region between dry and wet pampas, but differences exist in the degree of anthropogenic pressure. We used Victor Soft-catch® (Oneida Victor manufacturer, Euclid, USA) foot-hold traps # 1.5, iron-mesh box traps (40×40×120 cm) and stop-integrated locking neck snares (Luengos Vidal et al. 2003). Foxes were immobilized using ketamine hydrochloride (Ketamina®, Holliday Lab, Holliday-Scott S.A., Buenos Aires, Argentina; 11.6±3.7 mg/kg) and xylazine hydrochloride (2%, Rompum®, Bayer Lab, Buenos Aires, Argentina; 1.2±0.4 mg/kg) injected by hand; or in a few cases tiletamine hydrochloride-zolazepam hydrochloride (Zoletil® Laboratorio Virbac do Brasil, Industria y Comercio LTA, Sao Paulo, Brazil; 5.74±1.77 mg/kg) (Luengos Vidal 2003). The animals were recumbent within 5–10 min and handling time averaged 25 min (unpublished data).

Captured individuals were classified *a priori* into three age classes: pups, juveniles and adults, on the basis of tooth wear (Crespo 1971, McKenzie 1993, Gipson, 2000). Adults had fully erupted permanent dentition, juveniles had partially erupted permanent dentition, and pups had not yet acquired permanent dentition. These age-class groups were subsequently analysed for variation in other morphometrical and qualitative traits (Lemos and Cerqueira 2002). Although a few foxes were captured more than once, they were considered only once for the purpose of analysis. Data were collected on the following 16 morphological variables: BM=body mass (kg); DBC=external and distal distance between canines (mm): from gum line of C1 left to gum line of C1 right; HBL=head-body length (cm): from the tip of the nose to base of tail, measured to notch on sacrum; TL=tail length (cm): from the base of tail (sacrum) to the end of last caudal vertebra (tail tip), without fur; HL=head length (cm): from top of occipital bone (notch in back of skull) to nose tip; FL=fore-leg length: most dorsal point of scapula to base of foot;

EL=ear length: from the base of the ear to its tip, without fur; NC=neck maximum circumference (cm); FPL=front right pad length (mm, four measurements: 1=total pad length, 2=total pad width, 3=interdigital pad length, and 4=interdigital pad width); and BPL=back left pad length (mm, four measurements: 1=total pad length, 2=total pad width, 3=interdigital pad length, and 4=interdigital pad width).

It was not always possible to measure every variable on every individual, owing to rapid recovery from anaesthesia or presence of an existing limb lesion. As a result, there is some variation in sample sizes for each parameter. Foxes were weighed to the nearest 0.1 kg with a 10-kg spring balance (Pesola®, PESOLA AG, Baar, Switzerland). Tooth, ear and foot measurements were taken to the nearest 0.1 cm with vernier calipers. All other measurements were taken to the nearest 1.0 cm with a measuring tape. Capture, handling and marking procedures followed the guidelines of the American Society of Mammalogists (1998) (Animal Care and Use Committee) and were authorised by the Ministerio de Asuntos Agrarios, Provincia de Buenos Aires.

Data were analysed using SPSS PC version 10.0.5 software for Windows XP (SPSS Inc, Chicago, IL, USA). Assumption of normality was tested using the Kolmogorov-Smirnov and MAXDIFF statistics (Lilliefors 1969). While most measurements were normally distributed, EL deviated significantly from normality (MAXDIFF: 0.37; $p < 0.0001$). Where data deviated significantly from a normal distribution, non-parametric equivalent tests were used. Statistics included Student's t-test, independent-samples T-test using Levene's test for equality of variances, non-parametric Mann-Whitney tests and multivariate methods (discriminant and principal component analyses). Sexes were pooled for multivariate analyses.

We captured 85 individual foxes a total of 129 times (1–4 times each). Samples were categorized by sex and age. Mean values and standard deviations for the measurements of each age-sex category are given in Table 1. The males of the three classes of ages were heavier than the females; however, the largest differences were amongst adults (infants, $t=1.97$ $p=0.089$, $n=9$; juveniles, $t=2.26$; $p=0.040$, $n=16$; adults, $t=5.16$; $p=0.000$, $n=55$). While infants and juveniles were similar for most measurements considered (infants=93.8% of measurements showed no difference, juveniles=81.9%), adult males were taller (by the effect of HF: $t=5.260$; $p=0.0000$, $n=41$), longer (due to a longer tail, TL: $t=2.75$; $p=0.008$, $n=54$), with a thicker neck (ND: $t=5.17$; $p=0.001$, $n=48$) and larger foot pads (FP1: $t=3.07$; $p=0.004$, $n=46$; FP2: $t=2.04$; $p=0.047$, $n=47$; PP2: $t=1.45$; $p=0.05$, $n=49$) than adult females.

The general sexual similitude between adult characteristics was 64% (7:16). On average adult females ($n=24$) were approximately 21% lighter (BM), 3%–7% smaller if we consider linear measurements (HBL, TL, HL), and 7%–8% shorter (FL, EL) than adult males ($n=31$). The proportional difference in BM was similar between juvenile males and females ($n=9$, $n=9$, respectively), but the relationship in linear measurements was almost double (approximately 3%–12%).

Table 1 Statistical parameters (n, range and means \pm SD) for morphometrical measurements of each sex and age of Pampas fox, Buenos Aires Province during 1999–2004.

Age Sex	Adult		Juveniles										Infant																				
	Males					Females					Males					Females																	
	n	Min	Max	Mean	SD	n	Min	Max	Mean	SD	n	Min	Max	Mean	SD	r	M/F	n	Min	Max	Mean	SD	n	Min	Max	Mean	SD	r	M/F				
Female	n	Min	Max	Mean	SD	r	M/F	n	Min	Max	Mean	SD	r	M/F	n	Min	Max	Mean	SD	r	M/F	n	Min	Max	Mean	SD	r	M/F					
BM	22	2.4	5.75	4.67	0.86	31	4	8	5.95	0.96	21.56	8	3	5.75	4.11	0.9	8	3.75	6.5	5.22	1.04	21.3	3	1.4	2.2	1.78	0.4	6	1.7	3.5	2.6	0.64	31.4
DBC	22	2	2.6	2.34	0.16	28	1.13	3.4	2.44	0.41	4.12	8	1.9	2.37	2.21	0.2	8	1.36	3.7	2.4	0.64	7.78	2	1.3	2.2	1.75	0.6	4	1.98	2.13	2.05	0.07	14.74
HBL	21	59	72	64.98	4.02	26	59	80	68.33	4.58	4.9	8	50.5	68	59.88	5.7	8	61	86	66.5	8.11	9.96	2	45	59	52	9.9	4	47	51.5	49.63	2.06	-4.79
TL	23	26.5	39	33.26	3.2	31	28	43	35.82	3.5	7.15	8	27	34.5	30.31	2.7	8	31	38	34.25	2.67	11.5	2	19.5	29.5	24.5	7.1	4	28	40	32.75	5.85	25.19
FL	19	11.5	14.5	13.27	0.78	25	13	16	14.44	0.68	8.05	5	13	14.5	13.5	0.7	8	14	16	14.44	0.73	6.49	2	11	13	12	1.4	4	11	15	12.63	1.97	4.95
HL	23	13.5	20	16.67	1.58	27	15.3	19.5	17.17	1.07	2.92	8	15	18	16.13	1.1	8	14	19	16.63	1.53	3.01	2	13.5	15	14.25	1.1	6	13	17	14.5	1.52	1.72
ND	21	19	26	21.6	1.73	27	20	28	24.31	1.87	11.18	8	16	25	20.25	3.1	7	19	28	22.79	2.83	11.1	2	13.5	21	17.25	5.3	2	15	15	15	0	-15
FPL1	22	1.96	4.4	3.54	0.55	26	2.97	4.9	3.79	0.44	6.5	7	3.06	4.5	3.69	0.5	9	2.78	4.3	3.73	0.45	0.93	2	3	3.2	3.1	0.1	5	2.8	3.7	3.31	0.35	6.4
FPL2	21	0.75	1.8	1.31	0.28	25	1.1	2.78	1.63	0.4	19.72	7	1.1	1.8	1.46	0.3	8	0.93	2.7	1.62	0.54	9.49	2	1.5	1.9	1.7	0.3	3	1.27	1.45	1.34	0.1	-26.9
FPL3	22	1.4	3.69	2.7	0.45	25	1.1	3.7	2.99	0.51	9.68	7	2.3	3	2.78	0.2	9	2.63	3.8	2.96	0.35	6.18	2	2.4	2.4	2.4	0	5	1	3.4	2.22	1.02	-8.11
FPL4	22	1.3	2.5	1.73	0.25	26	1.3	2.88	1.9	0.41	8.86	7	1.13	2	1.7	0.3	9	1.59	2.95	2.12	0.54	20.1	2	1.4	1.9	1.65	0.4	5	1.64	2.6	1.98	0.4	16.58
BPL1	22	1.3	4.1	3.38	0.6	28	1.86	6.2	3.66	0.74	7.67	7	1.55	3.5	2.95	0.7	9	1.9	4.4	3.56	0.72	17.1	2	2.9	3.7	3.3	0.6	5	1.84	3.2	2.52	0.66	-31.2
BPL2	21	0.82	1.9	1.24	0.29	28	0.83	2.64	1.35	0.37	7.6	7	0.86	1.56	1.22	0.2	8	0.89	1.4	1.25	0.18	2.53	2	1.2	1.4	1.3	0.1	3	0.85	1.1	1.02	0.14	-27.9
BPL3	22	1.06	2.85	2.37	0.43	28	1.08	3.47	2.63	0.49	9.99	7	2.15	3.3	2.46	0.4	9	0.7	3	2.35	0.65	-4.64	2	2.4	2.5	2.45	0.1	5	0.84	2.8	1.91	0.92	-28.4
BPL4	22	1	2.4	1.42	0.36	27	1.08	2.44	1.52	0.36	6.55	7	1.12	2.8	1.55	0.6	9	1.15	2.35	1.54	0.37	-0.17	2	1.1	1.2	1.15	0.1	5	1	2.4	1.66	0.69	30.72
BPB1	21	1.6	11.8	7.12	1.71	25	6.13	18.1	7.12	2.26	1.32	8	5.83	7.23	6.57	0.5	9	1.21	9.05	6.92	2.35	5.05	2	5.8	6.7	6.25	0.6	5	1.4	7.6	4.36	2.8	-43.4

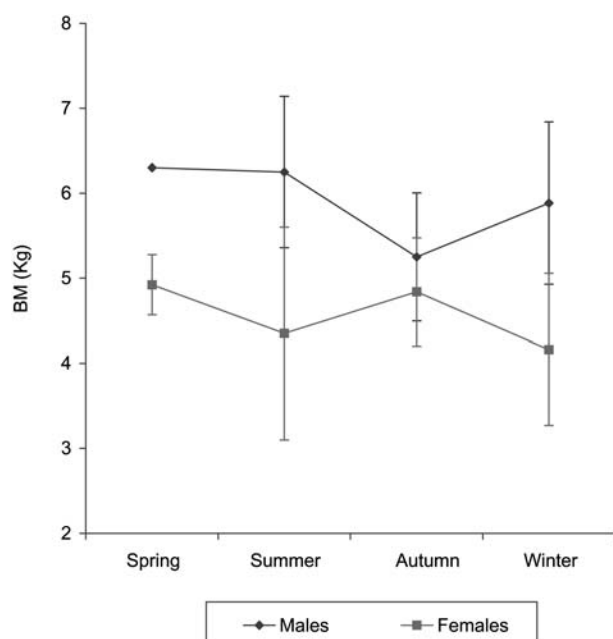


Figure 1 Seasonal variation in body mass of *Pseudalopex gymnocercus* in the Argentine Pampas with regard to sex. Sample size (males and females, respectively): spring 1, 2; summer 8, 4; autumn 6, 4 and winter 16, 14.

There was no significant effect of seasonality (Figure 1) on the body mass of adults, nor years (GLM, $p > 0.09$; season: $F = 2.55$; year: $F = 1.14$; season \times year: $F = 0.44$; season \times sex: $F = 0.65$; year \times sex: $F = 0.92$; season \times year \times sex: $F = 0.55$), sex being the only significant effect (GLM, $F = 10.31$, $p = 0.004$).

We used the 16 morphological parameters and sex in a principal component analysis to analyze the morphological variation at a population level. The first two principal components accounted for 46% of the total variance. The component loadings for PC1 were mostly positive (except BM) and higher values were related to BM and body measurements, thus indicating general size. Higher loadings of components of PC2 were related to the relationship pad width/length and could be interpreted as pad shape factors. Plotting PC1 and PC2 principal components it is possible to observe the three age groups in relation to the X-axes and animal size (PC1), which explains 35% of the variation, and a less evident sexual segregation in relation to the Y-axes and the shape of the pads (CP2), which only explain 11% of the variation (Figure 2).

Discriminant analysis was successful in separating the three age categories (Wilks $\lambda = 0.13$, $p < 0.001$ and 0.61, $p = 0.611$ for 1st and 2nd discriminant functions, respectively). Projection of the specimen scores for the first two discriminant functions revealed a clear separation between the three age class categories (Figure 3A) and a slight overlap between adults and juveniles resulting from wider variation in adults. The classification of the discriminant analysis had 91.1% of original grouped cases correctly classified. A discriminant analysis using characters easy to measure in the field and showing large standardised canonical discriminant was still successful in separating the three age class categories, with a

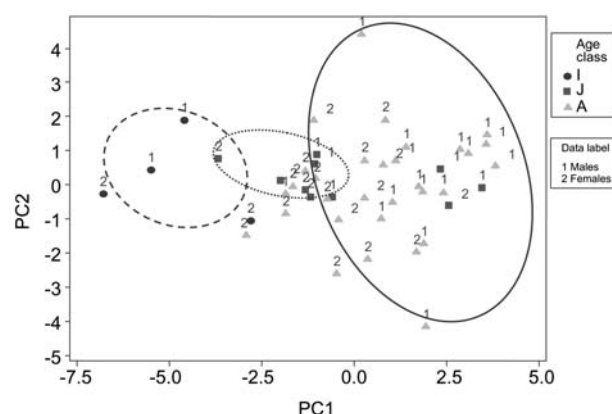


Figure 2 Principal component analysis of 16 morphological parameters recorded from *Pseudalopex gymnocercus* live-trapped in the Argentine Pampas. Labels: 1, male; 2, female. Age classes: 1, infant; 2, juvenile; 3, adult. The ellipses include 80% of the points of each age classes.

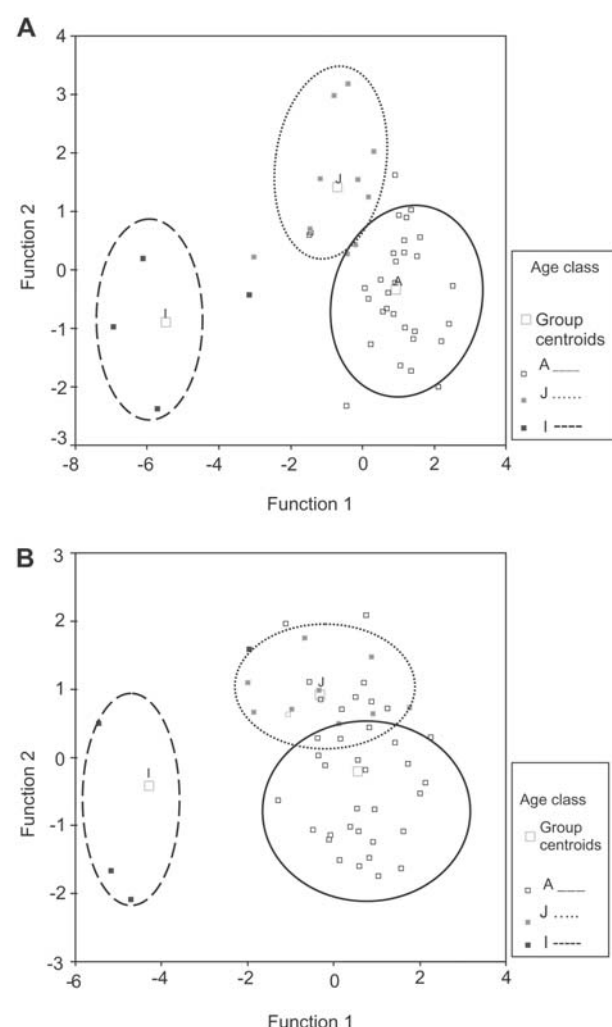


Figure 3 Discriminant functions for morphological parameters from *Pseudalopex gymnocercus* in the Argentine Pampas: (A) using all the measurements (above), (B) (below) considering BM, sex, TL, HBL and FL. Age classes: 1, infant; 2, juvenile; 3, adult. The ellipses include 80% of the points.

cumulative percentage of 89% for the 1st function (Figure 3B; Wilks $\lambda=0.29$, $p<0.001$ and 0.82, $p=0.120$ for 1st and 2nd discriminant functions, respectively); the 71.2% of original grouped cases was correctly classified.

Morphological sexual differences in our Pampas fox population were not very strong, although differences in body mass (20% approximately) were mainly associated with sex and not with other factors, such as season or years. In other fox species (e.g., Warrick and Cypher 1999), observed changes in body mass tracked availability in prey or weather conditions. Temporal homogeneity of the body weights of Pampas foxes may be related to a chiefly omnivorous diet (Castillo 2003), and to the fact that most of the animals came from areas where the availability of food was high relative to other areas (D. Birochio unpublished data), suggesting that foxes would probably find adequate food all year round.

Intersexual dimorphism in body mass in other fox species is not strong either (e.g., *Alopex lagopus* (L. 1758): 19% – Prestrud and Nilssen 1995, 20% – Warrick and Cypher 1999; *Vulpes vulpes* (L. 1758): 16% – Cavallini 1995), and differences in linear measurements in all these cases ranged from 3% to 8%. The lack of a larger variation may reflect monogamy, paternal care or perhaps little competition between sexes (Prestrud and Nilssen 1995). Although little is known of the reproductive behaviour of Pampas foxes the dimorphism observed in this study seems to follow this pattern and is supported by some field observations (Lucherini et al. 2004).

From a practical viewpoint, the three age classes (infants, juveniles and adults) selected *a priori* based on tooth features showed little divergence with a *posteriori* multivariate analysis, which thus supported the field classification. The three *a priori* groups were morphometrically distinct not only in their general size, as expected for different stages of development, but also in the shape of their pads which may be a reflection of secondary sexual characters. A satisfactory age class classification was possible using only five traits (BM, TL, HBL, Sex, FL), with a 71.2% probability of correctly classifying an individual. These five measurements are relatively easy to record in the field and provide a more objective classification than the use of dental characteristics alone.

Geographical variation in body size of adults is not rare in other fox species (Gortazar et al. 2000), and variations along a latitudinal gradient have been demonstrated for several species [*Vulpes vulpes* Cavallini 1995, *Urocyon littoralis* (Baird, 1858) Wayne et al. 1991, *Alopex lagopus* Gehrt and Fritzell 1999, *Pseudalopex griseus* (Gray, 1837) Jiménez 1995]. The mean adult weight body reported here for *Pseudalopex gymnocercus* are similar to that of other studies where similar data are available; although they belong to potentially different subspecies, living in different habitats, and with different inter-specific competitor conditions (Craviño et al. 1999 vs. Crespo 1971 and this study).

Although these three Pampas fox populations are spread longitudinally (more than 1000 km between Crespo 1971 and Craviño et al. 1999; this study is approximately 200 km from Crespo 1971 and 800 km from Craviño et al. 1999), they present a small latitudinal variation [Crespo (1971)=37°00'S–65°00'W, Craviño et al. (1999) and this study=38°03'S–62°00'W]. Therefore, to

achieve a better understanding of the validity of the current subspecies classification, it would be necessary to collect more morphological and ecological data throughout the species latitudinal range and in potential overlapping areas with taxonomically related species whose relations are unclear (e.g., *Pseudalopex griseus*) and where potential competitors occur [i.e., *P. griseus*, *P. culpaeus* (Molina, 1782) and *Cerdocyon thous* (L.1766)]. These data have to be collected using clear morphometrical protocols, with detailed descriptions for each measurement to allow comparison with other work.

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