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Research Article

Morphometric Evaluation of the Relationship Between the Distal Femur and Proximal Tibia of the Dogs

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ABSTRACT

In this study, 42 adult dogs, comprised of 25 males and 17 females, with 18 different morphological types from the heterogeneous population were used. A total of 4 osteometric measurements of the femur and tibia were taken. After calculating the mean and standard deviation values of 42 adult dogs (SPSS 21.0 program), the T-test was applied to observe the significance of the difference between the mean values of both sexes. Correlations were observed between osteometric measurements of the femur and tibia. As a result, regression formulations were created to make independent estimations of both the femur "greatest breadth of the distal end" and tibia "greatest breadth of the proximal end". The formulations formed had a high specificity value (R2). Hence, while sexual dimorphism was not observed on the measurements, the data produced in this study will contribute to the knee joint operations as well as to the identification of the same individual in mass burial contexts in zooarchaeological studies.

Keywords: Correlation, dog, femur, morphometry, tibia

Köpeklerin Distal Femur ve Proksimal Tibiası Arasındaki İlişkinin Morfometrik Değerlendirimesi

ÖZET

Bu çalışmada heterojen popülasyondan 18 farklı morfolojik tipe sahip 25 erkek ve 17 dişi olmak üzere 42 yetişkin köpek kullanıldı. Femur ve tibiadan toplam 4 osteometrik ölçüm alındı. Ortalama ve standart sapma değerleri hesaplandıktan sonra, her iki cinsiyetin ortalama değerleri arasındaki farkın anlamlılığını gözlemlemek için T testi uygulandı. Femur ve tibianın osteometrik ölçümleri arasında korelasyonlar gözlendi. Tibia'nın proximal'i ve femur'un distal'inde maximum genişlik ölçümleri hakkında bağımsız tahminler yapmak için regresyon formülasyonları oluşturuldu. Oluşturulan formülasyonlar yüksek bir özgüllük değerine (R2) sahipti. Dolayısıyla, ölçümlerde cinsel dimorfizm görülmezken, bu çalışmada ele edilen veriler diz eklemi operasyonlarına ve zooarkeolojik çalışmalarda toplu gömülme durumlarında aynı bireyin tanımlanmasında katkı sağlayacaktır.

Anahtar Kelimeler: Korelasyon, köpek, femur, morfometri, tibia

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Introduction

Dogs have different sizes and visual morphologies, and skull typology has been widely used to distinguish and define morphological types (Stockard, 1941; Komeyli, 1984; Brehm et al., 1985; Regedon et al., 1991; Onar, 1999; Onar et al., 2001). With this, long bone morphometry was used as the most basic element in determining the visual morphological characteristics such as body weight and shoulder height of different types of dogs and equations were created (Harcourt, 1974; Anderson et al., 1985; Anyonge, 1993; Wroe et al., 1999; Onar, 2005; Onar and Belli, 2005). Another important factor affecting visual morphology is sexual dimorphism, which reveals the size difference between males and females (Nganvongpanit et al., 2017). The fact that dogs from Yorkshire terrier to Dobermann have different sizes and morphological structures has brought with it intraspecific polymorphism (Jouve et al., 2001). Therefore, most of the common orthopaedic diseases observed in dogs are due to physical conformation and genetic predisposition (Boge et al., 2019). It was argued that many of the orthopaedic problems of long bones occur in the femur and its joints, and the conformation and geometry of the femur in dogs was emphasized (Ocal et al., 2012; Kara et al., 2018). The tibia, located distal to the femur, has also been evaluated for many races, both anatomically and angularly (Sabancı and Ocal, 2014, 2016; Aertsens et al., 2015). The knee joint, in which the femur and tibia participate, is a complex joint both morphologically and functionally (De Rooster et al., 2006; Gupte et al., 2007). This joint is composed of articulatio femorotibialis, articulatio femoropatellaris and articulatio tibofibularis proximalis and includes not only the femur and tibia as its components, but also the poximal parts of the patella and fibula (Dyce et al., 1987; Evans 1993; Bahadır and Yıldız, 2010). Articulatio femorotibialis, which is shaped between the condyles of the femur and tibia, is a ginglymus-like joint and carries the meniscus, which eliminates the compatibility between the rounded femur bone and the flat tibia bone plateau (Bahadır and Yıldız, 2010). The joint is also supported by distinctive cruciate ligaments (Dyce et al., 1987; Evans 1993). With this structural feature, this joint has been examined by many researchers in terms of both morphometric and angular aspects of the bones involved in its formation, and data that will contribute to clinical evaluations have been revealed (Ocal et al., 2012; Sabancı and Ocal, 2014, 2016; Kara et al., 2018).

In this study, using distal femur and proximal tibia morphometries, the relationship between these discordant parts of both bones was evaluated. Except for the angular measurements of both bones, the exchange of morphometric data with each other has been documented. Orthopedically speaking, this joint is a joint prone to injuries such as patella luxation, cruciate ligament ruptures and meniscus deformations due to its structural feature in dogs (Singleton, 1963; Barrett et al., 2009), it is of particular importance to know the relationship between the femur distal and tibia proximal extremity or end. In line with the morphometric data obtained, it was aimed to create the best regression equation to be used in possible prosthetic applications (Altunatmaz et al., 2019).

Material and Method

A total of 42 adult dogs, 25 male and 17 female, from a heterogeneous population (18 different sizes and skull types) were used in this study (Table 1). The femur and tibia bones of these dogs were used from the existing collections of Istanbul University-Cerrahpaşa Osteoarchaeology Practice and Research Centre, and the necessary ethics committee permission was obtained. (Permission of IUC Faculty of Veterinary Medicine, Unit Ethics Committee dated 01.07.2021 and numbered 2021/27).

The osteometric measurements of the femur and tibia by von den Driesch (1976), were taken as reference and a digital calliper was used to take the measurements. In the study, a total of 4 osteometric measurements of the femur and tibia were taken (figure 1). A total of 2 indices were calculated using these measurements.

Femur measurements:

Bd- Greatest distal breadth of the distal end

SD- Smallest breadth of diaphysis

Tibia measurements:

Bp- Greatest breadth of the proximal end

SD- Smallest breadth of diaphysis

Indices (Johnstone, 2004):

Femur index= Smallest breadth of diaphysis (SD)*100/ Greatest distal breadth of the distal end (Bd)

Tibia index= Smallest breadth of diaphysis (SD)*100/ Greatest breadth of the proximal end (Bp)

Figure 1. The osteometric measurements of femur and tibia (from von den Driesch 1976)

SPSS 21.0 (Version 21.0, SPSS Inc., Chicago, IL, USA). program was used for statistical calculation of osteometric measurements and calculated indices. After calculating the mean and standard deviation values of 42 adult dogs, T-test was applied to control the significance of the difference between the mean values of both sexes. After calculating the correlations between the osteometric measurements of the femur and the tibia, a

Table 1. Dog breeds and gender distribution

Breed	Number	Male	Female
French Bulldog	1	0	1
German Shepherd	6	3	3
Boxer	3	2	1
Kangal	5	4	1
Crossbreed	7	3	4
Clumber Spaniel	1	0	1
Great Dane	1	1	0
Mastiff	1	1	0
St. Bernard	2	1	1
Doberman	3	1	2
Terrier	3	2	1
Cocker Spaniel	1	1	0
Rottweiler	3	2	1
Canaan Dog	1	1	0
Irish Setter	1	0	1
Pekingese	1	1	0
Pointer	1	1	0
Siberian Husky	1	1	0

regression formulation was created to make independent estimations of both the femur "greatest distal breadth of the distal end" and the "greatest breadth of the proximal end" of the tibia. Thus, formulations thought to contribute to prosthesis applications were obtained. With these formulations, it was possible to estimate unknown distal femur or proximal tibia measurements from femur or tibia measurements. The statistical data obtained are presented in tables (Table 2 and 3) and the writing of the study was based on Nomina Anatomica Veterinaria (2017).

Results

In this study, the relationship between the distal femur and proximal tibia of dog breeds with different sizes and morphological appearances from the heterogeneous population was examined morphometrically. The femurs and tibias used were selected from individuals who did not have any bone problems. Through the statistical calculation, no homotypic variation was observed between the right and left bones of the same individual. For this reason, the mean values of the right and left bones of each individual were used. The osteometric measurements of the femur and tibia of these animals are presented in Table 2, taking into account the gender difference.

The osteometric measurements and indices of male dogs had a higher value than females. However, no statistically significant differences were observed between the mean values of males and females.

When CV values of osteometric measurements were calculated, the greatest change was observed in the measurement of "smallest breadth of diaphysis (SD)" in both genders (Table 3). CV value was calculated in the lowest index data.

High correlations were found between the osteometric measurements of each bone and with other bone measurements (Table 4). Low correlations were found between the measurement of the femur "Bd" and both

Table 2. Osteometric measurements and indices of the femur and tibia

Sex	Statistical	Bd	SD	Femur index	Bp	SD	Tibia index
MALE	Mean	36.19	15.20	41.91	39.50	15.03	38.05
	n	25	25	25	25	25	25
	SD	6.31	3.00	2.64	7.22	2.96	2.78
FEMALE	Mean	34.03	14.11	41.41	38.27	13.92	36.48
	n	17	17	17	17	17	17
	SD	4.55	2.52	3.87	5.09	1.88	2.53

Mean values in the same column are not statistically significant (P<0.05)

Table 3. CV values of osteometric measurements

Sex	Bd	SD	Femur index	Bp	SD	Tibia index
MALE	17.44	19.73	6.30	18.28	19.67	7.31
FEMALE	13.37	17.87	9.36	13.29	13.53	6.94

the femur and tibia indices, which were not statistically significant. Although this resulted in partially significant correlations in the measurement of "SD" of both the femur and tibia, their level were quite low. There was a very low negative correlation, not statistically significant, between the "Bp" of the tibia and the tibia index. The following equations were obtained when regression analysis was performed to estimate the distal femur and proximal tibia measurements (Femur: Bd and Tibia: Bp) participating in the formation of the articulatio genus. The level of determination (R2) of these equations was quite high.

F1=1.492+(0.867*T1) (R2=0.948)

T1=0.408+(1.093*F1) (R2=0.948)

Discussion

Dog breeds, from Yorkshire terrier to Dobermann, have different sizes and morphological structures, and show intraspecific polymorphism (Jouve et al., 2001). Therefore, although most of the common orthopaedic diseases observed in dogs are due to physical conformation and genetic predisposition (Boge et al., 2019), they are commonly found in the femur and its joints in the hind legs (Gregory et al., 1986; Knaus et al., 2003), which constitute the driving force of the trunk. These diseases are also claimed to occur in hind limbs by some previous studies (Ocal et al., 2012; Kara et al. 2018). Knee joint, which is a complex one both morphologically and functionally (De Rooster et al., 2006; Gupte et al., 2007), is a ginglymus-like compound joint (Dyce et al., 1987; Evans, 1993; Bahadır and Yıldız, 2010) due to the distal condylar structure of the femur and the plateau of the tibia (Bahadır and Yıldız, 2010). This incompatibility is corrected by intervening menisci (Evans, 1993). In the study, the morphometry of the articular surfaces of the femur and tibia, which is most emphasized in the hind limbs, was evaluated. The measurement of the smallest width of the diaphysis of the bones was also included in this assessment. Thus, the morphometry of the distal and proximal articular surfaces, which articulate in part in relation to the thinness index of the bones (Johnstone, 2004), has been associated. In these measurements, in which sexual dimorphism was not taken into account, it was observed that the CV change was the highest in the smallest diaphyseal widths of the bones, except for the measurements forming the joint. This was thought to be due to the fact that dog breeds of different sizes and morphological structures were used in the study, and therefore each breed had a different body structure.

It was observed that the difference between the measurements and indices of the femur and tibia between male and female individuals was not statistically significant. The values obtained for both genders were almost close to each other. Although sexual dimorphism refers to differences in size and form between male and female individuals (Nganvongpanit et al., 2017), it was probably due to the fact that few morphometric measurements of these bones did not reflect dimorphism. Although it was reported that breed differences, body weights and muscle mass should be taken into account in the evaluation of knee joint function using goniometric measurements, it was suggested that neither the gender of the dog nor the differences in the measured side affect the goniometric measurements of the knee joint (Sabancı and Ocal, 2016). Although information about the range of motion is widely used in many diseases and operations of the knee region (such as cruciate ligament injuries, partial patellectomy, total knee replacement) (Jandi and Schulman, 2007; Agostinho et al., 2011; Drygas et al. 2011; MacDonald et al., 2013; Skinnner et al., 2013), considering the morphometric measurements of the knee joint (Sabancı and Ocal, 2016), which is the joint most prone to orthopaedic diseases, would be

Table 4. Correlation analysis of indices with femur and tibia measurements

Measurements and indices	Femur			Tibia		
	Bd	SD	Femur index	Bp	SD	Tibia index
Bd	1.000	-	-	-	-	-
SD	0.924**	1.000	-	-	-	-
Femur index	0.160	0.522**	1.000	-	-	-
Bp	0.974**	0.937**	0.250	1.000	0.917**	-
SD	0.920**	0.948**	0.407**	0.917**	1.000	-
Tibia index	0.010	0.180	0.473**	-0.050	0.346*	1.000

**: P<0.01; *: P<0.05

beneficial. Total knee replacement operation is a well-known fact in the end-stage treatment of osteoarthritis findings, which are formed as a result of the rupture of the cranial cruciate ligament (Thitiyanaporn, 2020). We believe that knowing the morphometric measurements of the femur and tibia will increase the success in the selection of the prosthesis to be applied in these operations. It will make a great contribution especially to the evaluations at the racial level. In line with the morphometric data obtained in our study, the creation of the best regression equation for estimating the other measurement from a single bone dimension for use in possible prosthetic applications (Altunatmaz et al., 2019; Thitiyanaporn, 2020), is not only in terms of knee joint operations, but also in zoo archaeological studies. It will also contribute to the identification of individual bones. Thus, regression formulations will be available for individual identification from mixed burials.

Conclusion

As a result, while no sexual dimorphism was observed in the linear morphometric measurements and indices of the distal femur and proximal tibia, the level of determination (R2) of the regression formulas created using these measurements, is quite high. There are high correlations within and between the femur and tibia. It is believed that morphometry of the femur and tibia, which is the main element forming the knee joint, will contribute to the selection and creation of prosthesis operations such as total knee replacement.

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Conflict of interest

The authors declare that they have no conflict of interest in this study.

References

Aertsens, A., Alvarez, J.R., Poncet, C.M., Beaufrère, H., Rgetly, G.R. (2015). Comparison of the tibia plateau angle between small and large dogs with cranial cruciate ligament disease. Veterinary and Comparative Orthopaedics and Traumatology, 28, 385–390. https://doi.org/10.3415/VCOT-14-12-0180

Agostinho, F.S., Rahal, S.C., Miqueleto, N.S.M.L., Verdugo, M.R., Inamassu, L.R., El-Warrak, A.O. (2011). Kinematic analysis of Labrador retrievers and Rottweilers trotting on a treadmill. Veterinary and Comparative Orthopaedics and Traumatology, 24, 185–191. https://doi.org/10.3415/VCOT-10-03-0039

Altunatmaz, K., Eravcı-Yalın, E., İnal-Günay, B., Şadalak-Mckinstry, D.J., Sevim, Z.T., 2019: Treatment with custom partial condyle prosthesis of a comminuted femoral condyle fracture in a dog: a case report. Turkish Journal of Veterinary and Animal Sciences, 43, 140-145. doi:10.3906/vet-1807-115

Anderson, J.F., Hall-Martin, A., Russell, D.A., (1985). Long-bone circumference and weight in mammals, birds, and dinosaurs. Journal of Zoology, 207, 53-61. https://doi.org/10.1111/j.1469-7998.1985.tb04915.x

Anyonge, W., (1993). Body mass in large extant and extinct carnivores. Journal of Zoology, 1993; 231: 339-350. https://doi.org/10.1111/j.1469-7998.1993.tb01922.x

Bahadır, A., Yıldız, H. (2010). Veteriner Anatomi. Hareket Sistemi ve İç Organlar. Ezgi Kitabevi. Bursa.

Barrett, E., Barr, F., Owen, M., Bradley, K. (2009). A retrospective study of the MRI findings in 18 dogs with stifle injuries. Journal of Small Animal Practice, 50, 448–455. https://doi.org/10.1111/j.1748-5827.2009.00822.x

Boge, G.S., Moldal, E.R., Dimopoulou, M., Skjerve, E., Bregström, A. (2019). Breed susceptibility for common surgically treated orthopaedic diseases in 12 dog breeds. Acta Veterinari Scandinavica, 61, 19. https://doi.org/10.1186/s13028-019-0454-4

Brehm, von H., Loeffler, K., Komeyli, H. (1985) Schädelformen beim Hund. Anatomia Histologia Embryologia, 14, 324-331. https://doi.org/10.1111/j.1439-0264.1985.tb00828.x

De Rooster, H., de Bruin, T., Van Bree, H. (2006). Morphologic and functional features of the canine cruciate ligaments. Veterinary Surgery, 35, 769–780. https://doi.org/10.1111/j.1532-950X.2006.00221.x

Drygas, K.A., McClure, S.R., Goring, R.L., Pozzi, A., Robertson, S.A., Wang, C. (2011). Effect of cold compression therapy on postoperative pain, swelling, range of motion, and lameness after tibial plateau leveling osteotomy in dogs. Journal of the American Veterinary Medical Association, 238, 1284–1291. https://doi.org/10.2460/javma.238.10.1284

Dyce, K.M., Sack, W.O., Wensing, C.J.G. (1987). The hindlimb of the carnivores. In: K.M. Dyce, W.O. Sack & C.J.G. Wensing (Eds.), Textbook of Veterinary Anatomy, (pp.453–461), WB Saunders Company, Philadelphia.

Evans, H.E. (1993). Arthrology. In: H.E. Evans (Eds.), Miller's Anatomy of the Dog, (pp.219-257), Third ed., WB Saunders Company, Philadelphia.

Gregory, C.R., Cullen, J.M., Pool, R., Vasseur, P.B. (1986). The canine sacroiliac joint: preliminary study of anatomy, histopathology, and biomechanics. Spine 11, 1044–1048.

Gupte, C.M., Bull, A.M., Murray, R., Amis, A.A. (2007). Comparative anatomy of the meniscofemoral ligament in humans and some domestic mammals. Anatomia Histologia Embryologia, 36, 47–52. https://doi.org/10.1111/j.1439-0264.2006.00718.x

Harcourt, R.A. (1974). The Dog in Prehistoric and Early Historic Britain. Journal of Archaeological Science, 1, 151-175. https://doi.org/10.1016/0305-4403(74)90040-5

Jandi, A.S., Schulman, A.J. (2007). Incidence of motion loss of the stifle joint in dogs with naturally occurring cranial cruciate ligament rupture surgically treated with tibial plateau leveling osteotomy: Longitudinal clinical study of 412 cases. Veterinary Surgery, 36, 114–121. https://doi.org/10.1111/j.1532-950X.2006.00226.x

Johnstone, C.J., (2004). A Biometric Study of Equids in the Roman World, [Thesis submitted for PhD, University of York, Department of Archaeology], UK, https://etheses.whiterose.ac.uk/14188/1/428348.pdf

Jouve, S., Courant, F., Marchand, D. (2001). Disparity of skull morphology in dogs: geometrical morphometry approach. Journal of Morphology, 248:246.

Kara, M.E., Sevil-Kilimci, F., Dilek, Ö.G., Onar, V. (2018). Proximal and distal alignment of normal canine femurs: A morphometric analysis. Annals of Anatomy, 217:125-128. https://doi.org/10.1016/j.aanat.2018.02.006

Knaus, I., Breit, S., Künzel, W. (2003). Appearance of the sacroiliac joint in ventrodorsal radiographs of the normal canine pelvis. Veterinary Radiology&Ultrasound, 44, 148–154. https://doi.org/10.1111/j.1740-8261.2003.tb01263.x

Komeyli, H., (1984). Nasennebenhählen bei dolicho-, meso und brachyzephalen Hunden unter besonderer Berficksichtigung der rassespezifischen Schäidelformen. [Inaug Diss Vet-Meal, University Giessen] Germany.

MacDonald, T.L., Allen, D.A., Monteith, G.J. (2013). Clinical assessment following tibial tuberosity advancement in 28 stifles at 6 months and 1 year after surgery. The Canadian Veterinary Journal, 54, 249–254.

Nganvongpanit, K., Pitakarnnop, T., Buddhachat, K., Phatsara, M. (2017). Gender-related differences in pelvic morphometrics of the Retriever Dog breed. Anatomia Histologia Embryologia, 46, 51-57. https://doi.org/10.1111/ahe.12232

Nomina Anatomica Veterinaria. (2017). Sixth ed., Prepared by the International Committee on Veterinary Gross Anatomical Nomenclature (I.C.V.G.A.N.) and Published by the Editorial Commitee, Hannover (Germany), Gent (Belgium), Colombia (U.S.A),

Rio de Janeiro (Brazil).

Ocal, M.K., Sevil-Kilimci, F., Yildirim, I.G. (2012). Geometry of the femoral condyles in dogs. Veterinary Research Communications, 36:1-6. https://doi.org/10.1007/s11259-011-9504-8

Onar, V. (1999). A morphometric study on the skull of the German shepherd dog (Alsatian). Anatomia Histologia Embryologia, 28, 253-256. https://doi.org/10.1046/j.1439-0264.1999.00202.x

Onar, V. (2005). Estimating the body weight of dogs unearthed from the Van-Yoncatepe Necropolis in Eastern Anatolia. Turkish Journal of Veterinary and Animal Sciences, 2005, 29: 495-498. https://dergipark.org.tr/tr/pub/tbtkveterinary/issue/12545/151396

Onar, V., Belli, O. (2005). Estimation of shoulder height from long bone measurements on Dogs unearthed from the Van-Yoncatepe early Iron Age necropolis in Eastern Anatolia. Revue de Médecine Vétérinaire, 156: 53-60.

Onar, V., Özcan, S., Pazvant, G. (2001). Skull typology of adult male kangal dogs. Anatomia Histologia Embryologia, 30, 41-48. https://doi.org/10.1046/j.1439-0264.2001.00292.x

Regedon, S., Robina, A., Franco, A., Vivo, J.M., Lignereux, Y. (1991). Détermination Radiologique et Statistique des Types Morphologiques Crâniens chez le Chien: Dolichocéphalic, Mésocéphalie et Brachycéphalie. Anatomia Histologia Embryologia, 20, 129-138. https://doi.org/10.1111/j.1439-0264.1991.tb00752.x

Sabancı, S.S., Ocal, M.K. (2014). Lateral and medial tibial plateau angles in normal dogs. Veterinary and Comparative Orthopaedics and Traumatology, 27, 135–140. https://doi.org/10.3415/VCOT-13-04-0043

Sabancı, S.S., Ocal, M.K (2016). Comparison of goniometric measurements of the stifle joint in seven breeds of normal dogs. Veterinary and Comparative Orthopaedics and Traumatology, 29, 214-219. https://doi.org/10.3415/VCOT-15-05-0090

Singleton, W.B. (1963). Stifle joint surgery in the dog. Canadian Veterinary Journal, 4, 142–150.

Skinner, O.T., Kim, S.E., Lewis, D.D., Pozzi, A. (2013). In vivo femorotibial subluxation during weight-bearing and clinical outcome following tibial tuberosity advancement for cranial cruciate ligament insufficiency in dogs. The Veterinary Journal, 196, 86–91. https://doi.org/10.1016/j.tvjl.2012.08.003

Stockard, C.R. (1941). The Genetic and Endocrinic Basis for Diffences in Form and Behavior. American Anatomical Memoirs, no. 19. (pp. 1-775), Wistar Institute, Philadelphia.

Thitiyanaporn, C., Chantarapanich, N., Sompaisarnsilp, S., Thengchaisri, N. (2020). Comparison of canine stifle kinematic analysis after two types of total knee arthroplasty: A cadaveric study. Veterinary World, 13, 956-962. www.doi.org/10.14202/vetworld.2020.956-962

von den Driesch, A. (1976). A guide to the measurement of the animal bones from archaeological sites. Peabody museum bulletin 1, Harvard University, Massachusetts.

Wroe, S., Myers, T.J., Wells, R.T., Gillespie, A. (1999). Estimating the weight of the Pleistocene marsupial lion, Thylacoleo carnifex (Thylacoleonidae: Marsupialia): implications for the ecomorphology of a marsupial super-predator and hypotheses of impoverishment of Australian marsupial carnivore faunas. Australian Journal Zoology, 47, 489-498. https://doi.org/10.1071/ZO99006