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Article

The largest known falconid

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With 3 figures and 2 tables

Abstract: The caracaras represent a characteristic faunal element of the Neotropics. Recently, a very large fossil species *Caracara major* from late Pleistocene of Uruguay was considered the largest known falconid. In the present contribution we describe a larger specimen belonging to a *Caracara* form from the late Pleistocene of the Buenos Aires province. The body mass estimation of this specimen clearly exceeds that of living caracaras species and, represents the largest known falconid (lowest body mass estimation nearly of 4500 grams). The diversification and extinction of large–sized caracaras may be correlated with the abundance of very large mammals, which may provide abundant large carcasses as a food resource, in the late Pleistocene-early Holocene.

Key words: fossil birds; Falconidae; *Caracara*; body mass estimation; Pleistocene extinctions.

1. Introduction

The diurnal birds of prey belonging to family Falconidae are divided in two subfamilies (based on Remsen et al. 2014 and references therein; but see systematic proposals recently published by Fuchs et al. 2015): Herpetotherinae**,** including the Laughing-falcon *Herpetotheres cachinnans* and forest falcons in genus *Micrastur* and subfamily Falconinae. The latter includes the tribe Falconini with the true falcons and allies (i.e., *Falco*, *Microhierax* and *Polihierax*) and the tribe Caracarini that are represented by the Spot-winged Falconet *Spiziapteryx circumcincta* and the caracaras (i.e., *Caracara*, *Phalcoboenus*, *Daptrius*, *Ibycter* and *Milvago*). Except for Falconini with a worldwide distribution, the rest of Falconidae concentrate their diversity in the Neotropics (White et al. 1994; Fergusson-Lees & Christie 2001). The family Falconidae belongs in the order Falconiformes, that traditionally also included accipitrids, osprey and secretary bird (modified after Remsen et al. 2014 and references therein).

The living members of the genus *Caracara* (formerly *Polyborus*, but see Banks & Dove 1992) are represented by: Southern Crested Caracara *Caracara plancus* from the Amazon River to Peru, south to Straits of Magellan; and the Northern Crested Caracara *Caracara cheriway* from southern North America, Cuba, Central America to northern South America (Dove & Banks 1999). A third and insular species, *Caracara lutosus* from Guadalupe Island, became extinct in the early twentieth century (Greenway 1967; Dove & Banks 1999).

There are several fossil species described from Pleistocene-Holocene deposits of North America and West Indies, most of which are referred to the genus *Caracara*. Wetmore (1920) described *Caracara latebrosus* from Holocene cave of Puerto Rico. *Caracara prelutosus* has been described based on several remains from Pleistocene deposits of Rancho La Brea, California (Howard 1938). *Caracara creightoni* Brodkorb 1959, is another palaeospecies reported from Pleistocene and probable Holocene deposits of Cuba

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and The Bahamas (Olson & Hilgartner 1982; Suárez & Olson 2001, 2003; Steadman et al. 2007). Olson (2008) described *Caracara tellustris*, reported from Holocene caves of Jamaica. Several characters indicate that this bird might have been incapable of flight. Jones et al. (2013) described *Caracara major*, a new species from the late Pleistocene of Uruguay that is probably the largest falconid species known. In contrast to *C. tellustris*, based on coracoidal anatomy, this species would have retained flying capabilities (Jones et al. 2013). Recently, Suárez & Olson (2014) reported a new fossil species of small Crested Caracara *Caracara seymouri* from late Pleistocene of Peru and Ecuador. This species is similar in size to the extinct species *C. creightoni* and much smaller and more gracile than living *Caracara* species (Suárez & Olson 2014).

In this work we report a new specimen of large caracaras from late Pleistocene outcrops of argentine pampas. We estimate the body size and body mass range of this specimen based on living birds of prey data. Based on these estimations and the ecological role of living caracaras we hypothesize some evolutionary implications of the increased body size in this Pleistocene caracara, the largest falconid bird known at the moment.

2. Locality and geological setting

The specimen was collected by J.L. Kraglievich and L.J. Parodi in the 1927 at an unknown locality on the Río Quequén Grande, Buenos Aires Province, Argentina. According to its record in the MACN collections, the stratigraphic provenance of the specimen is "upper Pampean" ("*Pampeano superior*"). In the Quequen River outcrops, this unit is currently recognized under the formal designation of La Chumbiada and Guerrero Members, basal and middle terms, respectively, of the Luján Formation (Fidalgo et al. 1973; Dillon & Rabassa 1985). By its content of fossil mammals (see Prado et al. 1987) both members have been referred to the Lujanian Stage-Age (late Pleistocene, *Equus Amerhippus neogeus* Biozone, Cione & Tonni 2005). Available dating for the basal La Chumbiada Member indicates an antiquity of 37.800 ± 2.300 radiocarbon years BP and was deposited during the Marine Isotope Stage 3 (Pomi & Tonni 2011; Cenizo et al. 2015). In different localities in the Pampean Region, the overlaying Guerrero Member was dated between 21 and 10 kyr BP (Tonni et al. 2003) probably corresponding to the Last Glacial Maximum (LGM, circa 20.5-19 kyr BP, Clark et al. 2009) or other cold-climate events (MIS 2, the beginning of the MIS 1, Tonni et al. 2003). Unfortunately, it is unknown in which of these two members the specimen was found.

2. Material and methods

The fossil material here described is hosted in the Collection of Vertebrate Palaeontology of the Museo Argentino de Ciencias Naturales (MACN-PV). The specimen include a distal tibiotarsus (MACN-PV 10533). The tibiotarsi of the following specimens (m = male; f = female) were used for morphological comparisons, morphometrics and body mass estimations. Extinct species: *Caracara prelutosus*: LACMH E-651; -58629; *C. major*: MNHN-615 holotype. Extant species: *C. plancus*: CFA-OR-027-1, CFA-OR-027-2, CFA-OR-027-3, MACN 54744, MACN 68548f, MACN 54834m, MNHN 6254, 6391, MLP-PV-OR 62m, MLP-PV-OR 311, MLP-PV-OR 719, MLP-PV-OR 695, MLP-PV-OR 694; *Falco femoralis*: MLP-PV-OR 695, MLP-PV-OR 404, MLP-PV-OR 548, MACN 53559, MACN 25899, MACN 54712m, MACN 54810f, MACN 54712m, MACN 54810f, MACN 54712m, MACN 54810f; *F. peregrinus*: MLP-PV-OR 695; *F. deiroleucus*: MACN 53559; *F. sparverius*: MNHN 5639, MACN 52439, MACN 52437, MLP-PV-OR-637, MLP-PV-OR-54, MLP-PV-OR-55, MLP-PV-OR-56, MACN 52412f, MACN 52443f, MACN 54752f, MLP-PV-OR-55f, MACN 52475m, MACN 52753m; *F. rusticolis*: USNM 567722f; *Herpetotheres cachinnans*: MACN 54484, MHNT 624, MHNT 1125; *Micrastur ruficollis*: CFA-OR-291, MHNT 1124; *M. semitorquatus*: CFA-OR-498, MHNT 1463, MHNT 1147; *Milvago chimachima*: MACN 23508, MACN 68438, MACN 54485m, MNHN 6264f; *M. chimango*: MACN 54711, MLP-PV-OR-59, MLP-PV-OR-57, MNHN 5637, MNHN 5638, MLP-PV-OR-60f, MACN 5695m, MACN 54809m, MACN 54695m; *Phalcoboenus* sp MLP 65; *Polihierax semitorquatus* MACN 54483f; *Spiziapteryx circumcincta* MACN 23601; *Buteogallus meridionalis* MNHN 6297; *Elanus leucurus* MNHN 5636; *Geranoaetus melanoleucus* MLP 843, MACN w/n, MACN 21113, MACN 54352f; *Rostrhamus sociabilis* MNHN 6324; *Pithecophaga jefferyi* USNM 226900; *Gyps himalayensis* USNM 19534m; *Harpyhaliaetus coronatus* MACN 23473; *Torgus tracheliotus* USNM 19990; *Sagittarius serpentarius* USNM 555730f; *Pandion haliaetus* USNM 610343m; *Vultur gryphus* MLP367; *Cathartes aura* MACN 54726, MACN 54832; *Coragyps atratus* MACN 54748, MLP 344, MNHN 6292m. **Institutional acronyms:** CFA-OR-: Ornithological Collection, Fundación de Historia Natural "Félix de Azara", Buenos Aires, Argentina; LACMHC: Los Angeles County Natural History Museum, U.S.A.; MACN and MACN-PV: Ornithological and Palaeontological Vertebrates Collections (respectively), Museo Argentino de Ciencias Naturales, Buenos Aires, Argentina; MHNT: Museu Historia Natural de Taubaté, Sao Paulo, Brazil; MLP-PV-OR: Extant Birds Collection of the División Paleontología de Vertebrados, Museo de La Plata, La Plata, Argentina; MNHN: Museo Nacional de Historia Natural, Montevideo-Uruguay; USNM: National Museum of Natural History, Smithsonian Institution, Washington D.C., U.S.A.

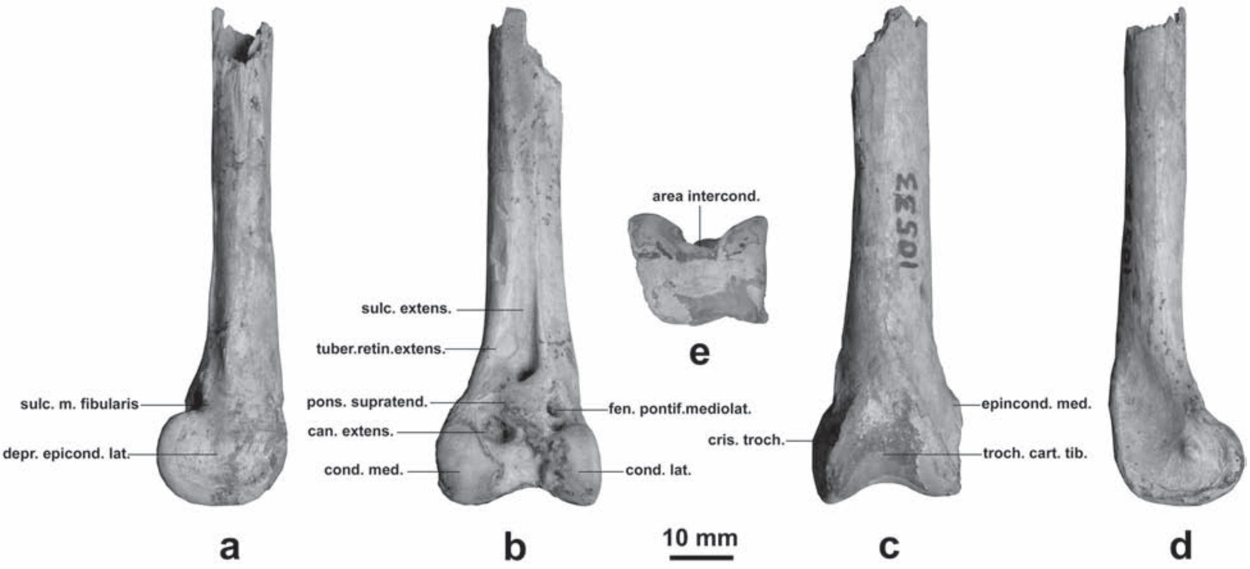

Fig. 1. Distal end of left tibiotarsus of *Caracara* sp. MACN-PV 10533 from late Pleistocene of Argentina. **a –** Lateral view; **b** – cranial view; **c** – caudal view; **d** – medial view; **e** – distal view, Scale bar = 1cm. Abbreviations: area intercond. = area intercondylaris; can. extens. = distal opening of canalis extensorius; cond. lat. = condylus lateralis; cond. med. = condylus medialis; cris. troch. = crista trochlearis; depr. epicond. lat. = depressio epicondylaris lateralis; epicond. med. = epicondylus medialis; fen. pontif .mediolat. = fenestra distolateralis pontifica; pons. supratend. = pons supratendineus; sulc. extens. = sulcus extensorius; sulc. m. fibularis = sulcus musculi fibularis; troch. cart. tib. = trochlea cartilaginis trochealis; tuber. retin. extens. = tuberositas retinaculum extensoris.

The measurement of maximum sagittal width of the distal tibiotarsus (in MACN-PV 10533) was used for body mass estimation from reduced major axis regression with log-transformed data from a sample of 27 species of Falconidae, Accipitridae, Sagittariidae, Pandionidae and Cathartidae (N = 35, see Fig. 3a) We selected the body mass data from these five non-phylogenetically related groups (see Hackett et al. 2008 and Jarvis et al. 2014) in order to cover the size variation of similar ecomorphs and avoid the extrapolation errors (Damuth & MacFadden 1990) due the large size of the fossil material here reported. For these reasons, we also estimated the body mass of MACN PV 10533 from a phylogenetically related sample of 14 species of Falconidae species (N = 20, see Fig. 3b). All measurements were taken with digital callipers to the nearest 0.01 mm.

Based on body mass estimations and mass ranges of living falconids we evaluate if the fossil specimen here studied may belong to the previously described fossil species *Caracara major*. We used body mass range data from American living falconids (data from Dunning 2008 and references therein). When maximum and minimum body mass registers are available we use this data taken into account sexual size dimorphism. When standard deviation (σ) is available, we assume that the maximum and minimum body mass limits are equal to mean body mass± 2(σ), respectively. Thereby, we assume a rough exploration of 95% of the specific population. Then, we calculate maximum body mass difference percentage (respect to maximum body mass limit) in order to compare the fossil specimen sizes (see Supplementary Material and Discussion section).

Taxonomic arrangement was according to Remsen et al. (2014 and literature cited therein). Anatomical terminology was based on Howard (1929) and Baumel & Witmer (1993). We follow the open nomenclature recommendations suggested by Bengston (1988).

3. Systematic palaeontology

Falconiformes Sharpe, 1874
Family Falconidae Vigors, 1824
Genus *Caracara* Merrem, 1826
Caracara sp.
Figs. 1-2

Referred material: MACN-PV 10533, distal end of the left tibiotarsus (Figs. 1-2).

Measurements: Maximum width of distal end, 27.13 mm; distal depth at medial trochlea, 21.68 mm; distal depth at lateral trochlea, 20.20 mm.

Description, comparisons and taxonomy: MACN-PV 10533 is broken at its distal third. The specimen is referred to Falconidae by the presence of a fenestra distolateralis pontifica (*sensu* Livezey & Zusi, 2006; absent in accipitrids), the Y-shaped pons supratendineus (Suschkin 1905; Jollie 1976), and the distal end being wider than dis-

Table 1. Comparative measurements (in millimetres).

	Caracara plancus[a]	*Caracara cheriway*[a]	*Caracara prelutosus*[a]	MACN PV 10533
Tibiotarsal distal width range	13.5-14.9	13-13.8	12.2-13.8	27.13

[a] Measurements taken from Howard (1938).

tal shaft (similar width in Accipitridae). The material shares with Caracarini the following characters: 1) in caudal view, wide and well excavated trochlea cartilaginis tibialis (narrow in *Micrastur*, shallow in *Falco*); 2) convergent condylar ridges (cristae trochleares) of this trochlea, and proximally extended (sub-parallel in Herpetotherinae, more proximally extended in *Falco*); 3) deep and well developed fenestra distolateralis pontifica (shallow with tiny holes in *Micrastur*, reduced in *Herpetotheres*, wider in *Falco*); 4) wide and obliquely oriented medial opening (i.e., distal opening of the canalis extensorius; elliptical and proximo-distally elongated in *Micrastur*; reduced and rounded *Herpetotheres*, similar in *Falco*); 5) wide and oblique pons supratendineus (narrow in *Micrastur*, more horizontally positioned in *Herpetotheres*, similar in *Falco*).

Although it is much larger, MACN-PV 10533 is more similar to the large caracaras *Caracara* and *Phalcoboenus* than the smaller *Milvago*, *Ibycter* and *Daptrius*. Tibiotarsi of *Phalcoboenus* species differs from that MACN-PV 10533 in having a much narrower shaft (especially distally), a shorter, shallower tendinal groove, and a different conformation of the supratendinal bridge (*sensu* Humphrey et al. 1993).

As seen in the extant and fossil species of the genus *Caracara*, the new specimen shows well-defined muscle scars on the cranial surface of the preserved shaft. Also the shape and proportions of the tibial condyles closely resemble that of *Caracara* species (Jollie 1976; Noriega et al. 2011). In addition, a small, but well-defined depression is located immediately distal to the fenestra distolateralis pontifica, a feature only observed in some individuals of *C. plancus*. However, the pampean specimen shows some differences with the known *Caracara* species. In cranial view, the medial scar for attachment of retinaculum extensorius is wider and relatively larger than observed in other *Caracara* species (more similar to that observed in *Herpetotheres*). In lateral and cranial aspect, the tuberosities for attachment of retinaculi m. fibularis are more distally positioned than in other Caracarini (including *Spiziapterix*). Cranially, medial tuberculum for attachment of retinaculi m. fibularis is positioned at the same level as the fenestra distolateralis pontifica. In other Caracarini (including *Caracara* species) the medial tuberculum is more proximally positioned and not adjacent to this fenestra. Likewise, the lateral margin of sulcus extensorius is very thick and protruding, with a development comparable to that observed in the larger *Falco* species. The cited differences with extant *Caracara* species and the very large size of this specimen suggest it could be related to the recently described *Caracara major* (but see Discussion and Tables 1-2). However, a well-founded assignment to the latter species is not possible, because the tibiotarsus of *C. major* is unknown.

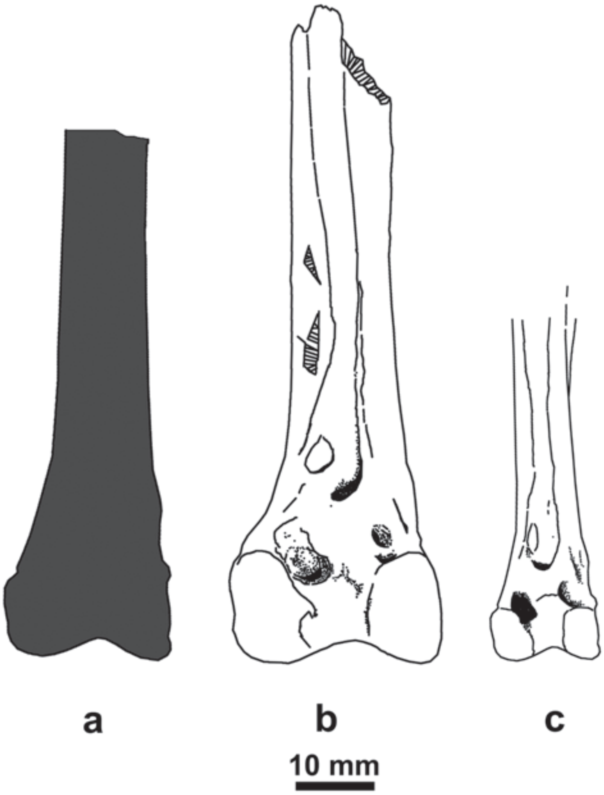

Fig. 2. Cranial views of distal portion of left tibiotarsi of Caracarini species compared with *Caracara* sp. MACN-PV 10533. **a** – Reconstruction of distal end of tibiotarsus of *Carcara major* assuming geometric scaling with *Caracara plancus*. **b** – *Caracara* sp. MACN-PV 10533. **c** – *Caracara plancus*. Scale bar = 1 cm.

4. Discussion

4.1. Body size of fossil material

Based on the large size of fossil specimen here described, we are tempted to estimate the body size and mass for this individual. Comparative measurements of tibiotarsal widths show that the fossil specimen here described is larger than those of other fossil and living *Caracara* species (see Table 1 and Fig. 2).

The maximum body mass range of an extant falconid is for a female Gyrfalcon (*Falco rusticolus*) with a

Table 2. Body mass estimation (in grams), body mass estimation errors and maximum body mass difference percentage of Pleistocene caracara fossil materials.

Fossil material/measurements	MACN PV 10533/tibiotarsal distal width[c]	MACN PV 10533/tibiotarsal distal width[d]	*Caracara major*/ femoral midshaft sagittal diameter
Body mass estimation	7259	4575	3862[a]
Body mass range estimation error	11227-4680	7265-2881	4639-3216[b]
Maximum body mass difference% respect to *C. major*	46.8	15.6	–

[a] Mean body mass estimations from JONES et al. (2013). [b] Body mass range estimation based on ALEXANDER (1983). [c] Based on general sample. [d] Based on falconid sample.

reported body mass of 2100 grams (FERGUSSON-LEES & CHRISTIE 2001 and references therein). The body mass estimation for *Caracara major* exceeds the 3700 grams (JONES et al. 2013), and up to now constituted the largest falconid species known. However, the body mass estimation from distal tibiotarsal width of MACN-PV 10533 is 7295 grams, well above the range of *C. major*, even considering the minimum body mass estimation error (11227 grams-4680 grams; see Table 2). But, as it was previously remarked (see Systematic Palaeontology section), the distal end width of tibiotarsus is expanded in falcons compared to accipitrids and cathartids tibiotarsii. This condition could generate an overestimation of the body size. The body mass estimation based on a sample of Falconidae species is 4575 grams (7266 grams–2881 grams, see Table 2), but it has the uncertainties of extrapolation errors (DAMUTH & MCFADDEN 1990).

We assume that the specific body mass range variation of fossil specimen here reported is comparable with those of living *Caracara* species. As was previously observed (BROWN & AMADON 1968; FERGUSSON-LEES & CHRISTIE 2001), *Falco* species show a very high reversed sexual size dimorphism (FERGUSSON-LEES & CHRISTIE 2001; KRÜGER 2005), while in Caracarini species females are only slightly larger than males (see FERGUSSON-LEES & CHRISTIE 2001; DUNNING 2008; Supplementary information of this work). Considering that, the analysis of body mass range variation registered in living *Caracara* species (maximum body mass difference of 48.4%; see Supplementary information) would not preclude that the body mass estimation from the distal fragment of tibiotarsus MACN-PV 10533 would be associated with *C. major* (body mass estimations difference of 46.8%; see Table 2). However, the maximum body mass difference of *Caracara* species corresponds with data from the Panama population of *C. cheriway* (data from DUNNING 2008). In this case, there is a high standard deviation in male sampling not observed in the Florida (United States) population of this species (see Supplementary information and DUNNING 2008). However, considering that body mass variation observed in *C. plancus* is much lower (maximum body mass difference observed is 13.3%, see Supplementary information), the inclusion of MACN-PV 10533 within *C. major* seems unlikely. The analysis of the estimated body mass from Falconidae sample (mean estimation of 4575 grams; maximum body mass difference is 15.6%, see Table 2) would not preclude the inclusion of studied material within *C. major* body mass range. But, the extrapolation uncertainties not offer a reliable estimation. However, the estimation of tibiotarsal dimensions of *C. major* assuming geometrical scaling (Fig. 2) suggests that MACN PV 10533 is considerable larger than the Uruguayan species.

4.2. Comments on the evolution of Pleistocene large caracaras

SUÁREZ & OLSON (2003) claimed that despite their modern paucity, the fossil record indicates that caracaras were much more diverse in the West Indies during the late Pleistocene-Holocene. Furthermore, the presence of *Caracara* species in North America is restricted to the late Pleistocene-Recent, which suggests late dispersion of the group in this continent (EMSLIE 1998), also in agreement with existence of suitable resources allowing the geographic expansion of caracaras. In addition, the caracaras from West Indies described by SUÁREZ & OLSON (2003) and OLSON (2008) are larger than their living counterparts. The presence of large-sized caracaras in the Pampean Region of Argentina

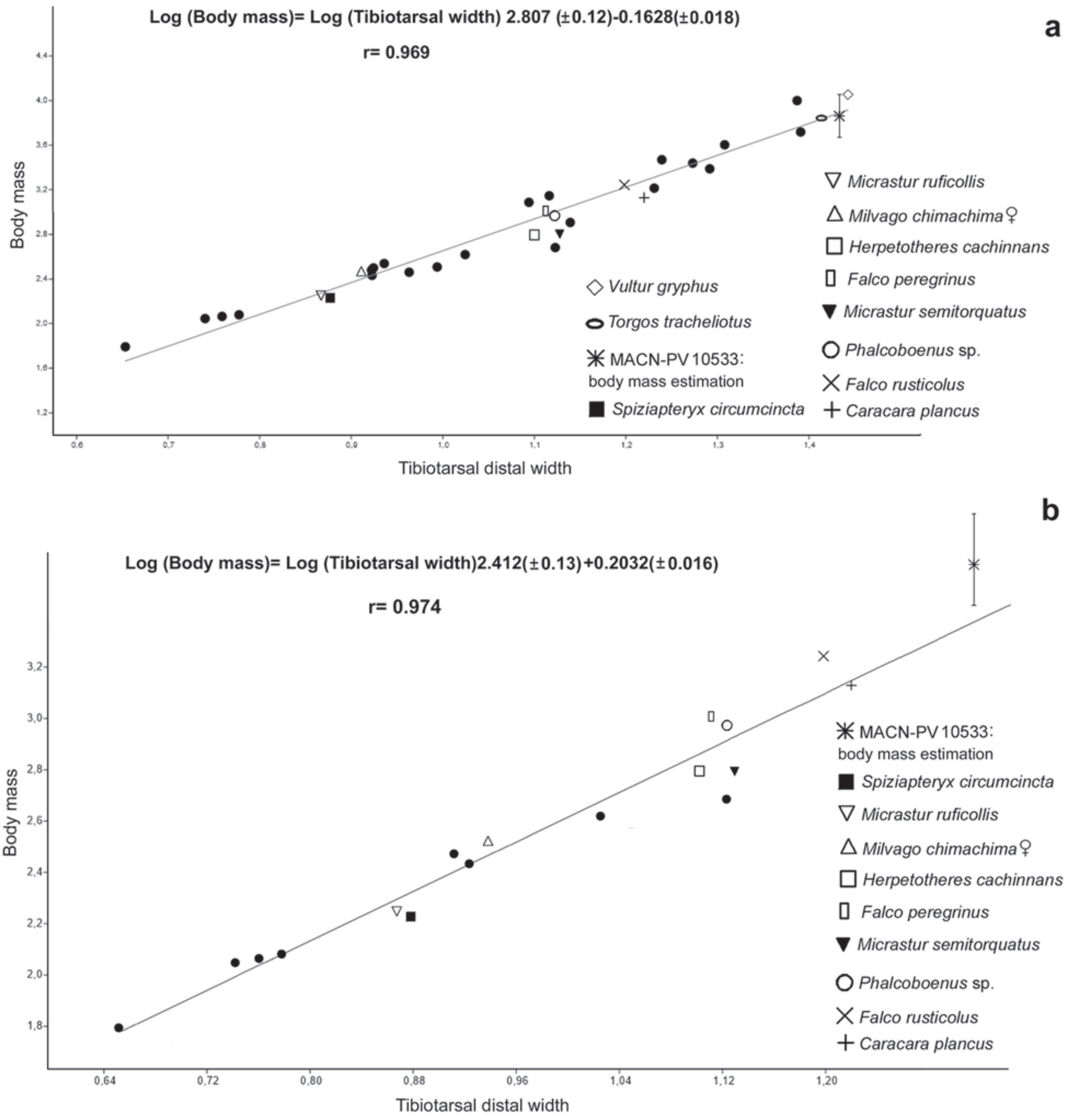

Fig. 3. Plot of linear regressions using reduced major axis (RMA): **A** – Tibiotarsal distal end width (in mm) plotted against body mass (in grams) for general sample (N = 35). **B** – Tibiotarsal distal end width (in mm) plotted against body mass (in grams) for falconid sample (N = 20). Regression equation (error of regression coefficients), Pearson's r correlation and body mass estimation and error range are shown. All axes are expressed in decimal logarithm scale. Some species labels (showed as black dots) were omitted for better visualization.

and Uruguay also seems to mimic this pattern.

Jones et al. (2013) proposed that *C. major* was probably the largest falconid species, and due to its large size the ecological role of the species may be somewhat different to that of living species of the clade. These authors propose that the large amount and size of megafaunal carrion could have favoured the large body size of *C. major*. Therefore, we suggest that megafauna favoured the diversification of caracaras in South America. This perspective is based on the very large *Caracara* specimen here reported and at least two other species recently described for the late Pleistocene of South America (Jones et al. 2013; Suárez & Olson 2014). A similar pattern was previously suggested for other large carrion vultures (Tonni & Noriega 1998; Alvarenga & Olson 2004; Alvarenga et al. 2008).

Molecular analyses indicate that several lineages of opportunistic or facultative scavenging caracarines diversified in South America during the last 14 Ma (Fuchs et al. 2012 and references therein). This diversification may be linked to the aridification of the environment with accompanying expansion of open habitat enabling an increase in the abundance of mammalian grazers that could serve as potential food resource (Jacobs et al. 1999). Tonni & Noriega (1998) suggested that the evolution of large predatory birds, mainly scavengers, was triggered by the development and evolutionary history of South American megafauna. These authors proposed that the carrion-feeding Cathartidae vultures were highly diversified and very widespread in the Pleistocene because of the abundance of carcasses of the megafaunal components. By the late Pleistocene-early Holocene, the extinction of all megamammals was probably the main factor that promoted the total or local extinction of several genera and species of cathartids. In this regard, the gigantic caracarines probably also became extinct in the Pampean Region following the extinction of megafauna (in agreement with Cenizo et al 2015, that proposed this idea for several groups of large scavenger birds). However, further studies and new findings of fossil caracaras would shed new light on this Pleistocene palaeofaunal patterns.

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Appendix

Supplementary material

It contains the following sheets: Body mass measurements; body mass estimations and linear regressions data; body mass range analysis based on data of Dunning (2008).

Measurements.

Species	**Body mass (grams)**	**Tibio-tarsus proximal width (mm)**
Falconidae		
Caracara plancus CFA-OR-027-1	1348	16.38
Caracara plancus CFA-OR-027-2	1348	18.52
Caracara plancus CFA-OR-027-3	1348	19.99
Caracara plancus MACN 54744	1348	16.94
Caracara plancus MACN 54834♂	1348	15.7
Caracara plancus MNHN 6254	1348	13.47
Caracara plancus MNHN 6391	1348	15.14
Caracara plancus MACN 68548♀	1348	
Caracara plancus MLP-PV-OR 62♂	1348	
Caracara plancus MLP-PV-OR 311	1348	
Caracara plancus MLP-PV-OR 719	1348	
Caracara plancus MLP-PV-OR 695	1348	
Caracara plancus MLP-PV-OR 694	1348	
Mean	**1348**	**16.59**
Falco peregrinus MLP-PV-OR 695	**1025**	
Falco deiroleucus MACN 53559	**481**	**13.27**
Falco femoralis MACN 25899	344	**9.99**
Falco femoralis MLP-PV-OR 404	344	
Falco femoralis MLP-PV-OR 548	344	
Mean	**344**	
Falco femoralis MACN 54712♂	271	**8.37**
Falco femoralis MACN 54810♀	416	**10.58**
Falco sparverius MNHN 5639	116	5.86
Falco sparverius MACN 52439	116	5.45
Falco sparverius MACN 52437	116	5.28
Falco sparverius MLP-PV-OR-637	116	6.03
Falco sparverius MLP-PV-OR-54	116	6.02
Falco sparverius MLP-PV-OR-55	116	5.94
Falco sparverius MLP-PV-OR-56	116	5.62
Mean	**116**	**5.74**
Falco sparverius MACN 52412♀	120	6.1
Falco sparverius MACN 52443♀	120	5.72
Falco sparverius MACN 54752♀	120	6.18
Falco sparverius MLP-PV-OR-55♀	120	5.94
Mean	**120**	**5.99**
Falco sparverius MACN 52475♂	111	5.29
Falco sparverius MACN 52753♂	111	5.7
Mean	**111**	**5.50**
Falco rusticolis USNM 567722 ♀	**1752**	**15.79**
Herpetotheres cachinnans MACN 54484	625	13.38
Herpetotheres cachinnans MNHT 624	625	12.2
Herpetotheres cachinnans MNHT 1125	625	12.2
Mean	**625**	**12.59**
Micrastus ruficollis CFA-OR-291	179	7.91
Micrastus ruficollis MNHT 1124	179	6.8
Mean	**179**	**7.36**
Micrastur semitorquatus CFA-OR-498	631	17.15
Micrastur semitorquatus MNHT 1463	631	11.6
Micrastur semitorquatus MNHT 1147	631	11.5
Mean	**631**	**13.42**
Milvago chimachima MACN 23508	316	8.6
Milvago chimachima MACN 68438	316	8.2
Mean	**316**	**8.4**
Milvago chimachima MACN 54485♂	**302**	**8.36**
Milvago chimachima MNHN 6264♀	**329**	**8.67**
Milvago chimango MACN 54711	295	8.65
Milvago chimango MLP-PV-OR-59	295	8.22
Milvago chimango MLP-PV-OR-57	295	8.57
Milvago chimango MNHN 5637	295	7.31
Milvago chimango MNHN 5638	295	7.99
Mean	**295**	**8.15**
Milvago chimango MLP-PV-OR-60 ♀	300	**8.07**
Milvago chimango MACN 5695♂	289	8.92
Milvago chimango MACN 54809 ♂	289	9.45
Milvago chimango MACN 54695♂	289	
Mean	**289**	**9.19**
Phalcoboenus sp MLP 65	**928**	**13.25**
Polihierax semitorquatus MACN 54483 ♀	**62**	**4.5**
Spiziapteryx circumcincta MACN 23601	**169**	**7.53**
Accipitridae		
Buteogallus meridionalis MNHN 6297	**808**	**13.78**
Elanus leucurus MNHN 5636	346	8.63
Mean	**346**	**8.63**
Geranoaetus melanoleucus MLP 843	2445	22.39
Geranoaetus melanoleucus MACN s/n	2445	17.19
Geranoaetus melanoleucus MACN 21113	2445	19.66
Mean	**2445**	**19.75**
Geranoaetus melanoleucus MACN 54352 ♀	**2751**	**18.75**
Rostrhamus sociabilis MNHN 6324	**322**	**9.86**
Pithecophaga jefferyi USNM 226900	**5232**	**24.6**
Gyps himalayensis USNM 19534 ♂	**10000**	**24.38**
Buteo jamaicensis USNM 552822 ♀	**1224**	**12.42**
Harpyhaliaetus coronatus MACN 23473	**2950**	**22.03**
Torgus tracheliotus USNM 19990	**6969**	**25.93**
Sagittariidae		
Sagittarius serpentarius USNM 555730 ♀	**4017**	**20.32**
Pandionidae		
Pandion haliaetus USNM 610343 ♂	**1403**	**13.07**
Cathartidae		
Vultur gryphus MLP367	**11300**	**27.72**
Cathartes aura MACN 54726	1220	21.11
Cathartes aura MACN 54832	1220	20.74
Mean	**1220**	**20.93**
Coragyps atratus MACN 54748	1640	21.38
Coragyps atratus MLP 344	1640	16.65
Coragyps atratus MNHN 6292 ♂	1640	13.04
Mean	**1640**	**17.02**
Tbt *Caracara* sp. indet. MACN PV 10533		**27.13**

Body mass estimations

		Estimated body mass (RMA) Tbt distal width 1	**Error +**	**Error -**
RMA Regression ALL SAMPLE (N = 35)		7259.280	11226.64	4680.209
RMA Regression				
Tibiotarsus_ width_ 1 vs. Body mass. log-log transformed				
Slope a:	2.807			
Intercept b:	-0.1628			
Std. err. a:	0.12031			
Std. err. b:	0.017534			
Chi squared:	0			
r:	0.96922			
r squared:	0.93938			
t statistic:	2.26E+01			
p(uncorrel):	1.16E-21			
Permutat. p:	1.00E-04			
p(a = 1):	2.60E-16			
95% bootstrapped confidence intervals:				
a: [2.57; 3.054]				
b: [-0.3977; 0.103]				
			Error +	**Error -**
RMA Regression FALCONIDAE (N = 20)		4575.138	7265.490	2881.002
RMA Regression				
Tibiotarsus_ width_ 1 vs. Body mass. log-log transformed				
Slope a:	2.4118			
Intercept b:	0.20321			
Std. err. a:	0.12905			
Std. err. b:	0.015874			
Chi squared:	0			
r:	0.97389			
r squared:	0.94846			
t statistic:	1.82E+01			
p(uncorrel):	4.87E-13			
Permutat. p:	1.00E-04			
p(a = 1):	2.20E-09			
a: [2.16; 2.696]				
b: [-0.04159; 0.436]				

Body mass range analysis

Family Falconidae	**Mean body mass (♂-♀) grams**	**Min**	**Max**	**Desv std**	**Mean + 2Desv std**	**Mean - 2Desv std**	**Maximum difference %**	**Maximum population difference %**
Daptrius ater	339-365	260	445				41.57	
Ibycter americanus	624	586	665				11.88	
Phalcoboenus megalopterus	788	780	795				1.89	
Caracara cheriway♂	1117			71	1259	965	23.35	29.66
Caracara cheriway♀	1220			76	1372	1068	22.16	
Caracara cheriway♂	834			133	1100	568	48.36	48.36
Caracara cheriway♀	953			63.2	1079.4	826.6	23.42	
Caracara plancus	1348	1266	1460				13.29	
Milvago chimachima	302-329	235	364				35.44	
Milvago chimango	296			30.9	357.8	234.2	34.54	
Herpetotheres cachinnans	583-667	544	800				32.00	
Micrastur plumbeus	180-191	172	213				19.25	
Micrastur mintoni	200-219	171	264				35.23	
Micrastur gilvicollis	209	170	262				35.11	
Micrastur mirandollei	549	542	556				2.52	
Micrastur semitorquatus	523-739	467	900				48.11	
Spiziapteryx circumcincta	141-196	124	228				45.61	
Falco columbarius♂	163			14.1	191.2	134.8	29.50	46.59
Falco columbarius♀	218			17.2	252.4	183.6	27.26	
Falco peregrinus pealei	894-1201	740	1595				53.61	
Falco peregrinus anatum♂	652			52.4	756.8	547.2	27.70	51.57
Falco peregrinus anatum♀	977			76.4	1129.8	824.2	27.05	
Falco peregrinus tundrius	598-959	528	1130				53.27	
Falco femoralis	271-416	208	500				58.40	
Falco sparverius	143-151	130	163				20.25	
Falco rufigularis	130-206	108	242				55.37	
Falco deiroleucus	339-623	338	654				48.32	
Falco mexicanus♂	560			36	632	488	22.78	53.07
Falco mexicanus♀	908			65.9	1039.8	776.2	25.35	
Falco rusticolus	1170-1752	960	2000				52.00	