Economic anatomy of the Brown Brocket deer (*Mazama gouazoubira*) and its relationship with other artiodactyls

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Abstract

Brocket deer constitute a broadly exploited resource for many present and past Neotropical hunter-gatherers. In this paper we present results of a butchery experiment on a Brown Brocket deer (*Mazama gouazoubira*) individual, which was employed to calculate gross yield indices (MUI, GUI and FUI) and meat return rates for this species. Then, results are compared with available data for larger cervids (caribou, huemul and white-tailed deer) and other artiodactyls <60 kg (impala and sheep) showing strong and positive correlation in all net returns, and similar gross utility frequencies at least for cervids from 18-180 kg live weight. More variability was found among return rates, suggesting interspecific comparison of processing costs is an issue which requires more data gathering.

1 Introduction

Mazama is the most diverse genus among South American cervids, with at least ten species (see contributions in Duarte & González 2010). The Brown Brocket deer (*Mazama gouazoubira*) is one of the most widely distributed and is a medium-small sized taxon, which weighs from 11 to 25 kg and inhabits secondary forests from the southern Amazon to south Chaco and Uruguay (Black-Décima et al 2010).

Brown Brocket deer (BBD) and other *Mazama* species constitute regular prey for many aboriginal communities (eg, Hill et al 1997). BBD is exploited by, among others, Aché groups in the Paraguayan Chaco (Hill & Padwe 2000) and Xavantes in Pantanal of Mato Grosso (Coimbra et al 2002). In the Argentinean Chaco, it was broadly hunted by historical Abipones (Dobrizhoffer 1967) and Mocovíes, groups who additionally employed their skins to manufacture ropes and drum patches among other artefacts (Paucke 1944:367). The current Toba and Wichí of the central Chaco value the ease with the deer is hunted and consider it and red brocket deer (*Mazama americana*) as preferred prey (Arenas 2003). These two ethnic groups have also developed a local taxonomy for both species taking into account their fur type and colour. They value the excellent quality of their meat, which is consumed roasted, or boiled in soups, or stewed. They also exploit bones, marrow, blood, viscera, and organs (specially the stomach, consumed in a special preparation called '*relleno de panza*', Arenas 2003:170). These groups developed many partial taboos and cultural issues on its consumption as well.

Archaeologically, morphological similarities between BBD and other medium-sized cervids sharing its distribution area, like *Mazama americana, Mazama nemorivaga, Mazama bororo, Mazama nana* and *Ozotoceros bezoarticus*, make it difficult to distinguish between these taxa skeletally and obscure our understanding of their past economic importance (see Acosta et al 2011). However, the remains of Brocket deer from levels dated ca 8000 years BP and other diverse prehispanic contexts suggests they were exploited early in the Holocene (see Nogueira De Queiroz & De Carvalho 2008). BBD have also been recorded in several Late Holocene sites (ca 2500 – 400 years BP) in the Chaco region (Kraglievich & Rusconi 1931), and lower Paraná wetland (Cione et al 1977; Caggiano et al 1978; Caggiano 1984; Sartori & Colasurdo 2011). Specimens identified as *Mazama* sp. have been recorded in archaeological sites located within its modern distribution area (see

Bonomo et al 2009; del Papa et al 2012; Medina & Pastor 2012; Santini & De Santis 2012).

1.1 Utility indices

As a part of his ethnoarchaeological research among the Nunamiut, Lewis Binford processed a set of caribou and sheep carcasses and measured the amount of meat, bone marrow and bone grease attached to each anatomical unit. Results were employed to develop a series of utility indices which he used to explain Nunamiut prey butchery, transport and consumption decisions (Binford 1978).

These frames of reference quickly became an essential tool for zooarchaeologists seeking to model skeletal part frequencies employing nutritionally meaningful variables. They remain essential methodological tools to explore trade-offs between prey processing time and transport distance, and, ultimately, decision-making process underlying subsistence strategies among hunter-gatherers.

Economic utility indices of primary products (meat, bone marrow and bone grease) are now available for many important large and medium-sized ungulates, like bison (Emerson 1990), horse (Outram & Rowley-Conwy), guanaco (Borrero 1990), hartebeest (Lupo 1998), impala (Lupo 1998, 2006), llama (Mengoni Goñalons 1991), wildebeest (Lupo 1998), and zebra (Lupo 1998, 2006), among others. In the case of cervids, indices have been proposed for three species: caribou (Binford 1978), huemul (Belardi & Gómez Otero 1998) and White-Tailed deer (Madrigal & Holt 2002; Madrigal 2004). These studies have shown strong similarities among them in their economic anatomy.

A less common and more recent concern for utility studies has been in gathering information on processing times, a critical variable to build return-rates or post-procurement part utility indices (Lupo 1998, 2006; Madrigal & Holt 2002; Madrigal 2004; Egeland & Byerly 2005). These works, theoretically grounded on the principles of human behavioural ecology, stress that field processing and transport costs should be calculated to develop more behaviourally meaningful butchery and transport models. Return rates are also important in order to rank each prey into an overall diet model.

1.2 Objective

The main purpose of this study is to present a set of economic utility indices obtained from a butchery experience of a single BBD. Our longer term aim is to generate a new frame of reference for the analysis of BBD fossil records, and we expect these results could be usefully applied to cervids or even artiodactyls of similar size and weight. There may be variability between species in utility based on differences in body size, habitat and locomotive habits (Madrigal & Holt 2002:746) and comparative studies are needed between our results and other available utility indices.

2 Materials and methods

An adult male BBD (CFA-12857), from Estación de Cría de Animales Silvestres (ECAS) located in Villa Elisa, Buenos Aires province, was deposited after its death in Fundación de Historia Natural Félix de Azara (Departamento de Ciencias Antropológicas, Universidad Maimónides). The specimen was in good health and died after a fight with another BBD. It was transported on the day of its death and frozen before processing.

Butchery was carried out by a technician employing metal knives and a scalpel. It was divided in three stages: 1) skinning; 2) dismembering; and 3) fleshing. Each stage was timed with a digital watch following this order: 1) forelimb; 2) hindlimb; 3) vertebral column and sternum; 4) pelvis and sacrum; and 5) head.

For meat recovery, units of butchering were defined following bone limits, though we observed that the cut angle was a fundamental variable in some cuts, especially in the segmentation of the appendicular skeleton (femur and scapula). All tissues were intended to be recovered but on the axial skeleton small amounts of meat remained attached to the bone, especially on the vertebral column.

The carcass was divided following the anatomical units employed by Binford (1978). However, for logical reasons, and given the small size of the individual, we treated some bones as a single unit. The units were as follows: skull, mandible with tongue, cervical vertebrae, thoracic vertebrae with ribs and sternum, lumbar vertebrae, pelvis with sacrum, scapula, humerus, radius with ulna, metacarpal with carpals, femur, tibia with astragalus and calcaneum, metatarsal with tarsals, and phalanges.

Once dismembered, each anatomical unit was weighed with the meat to obtain the gross weight. After processing the meat, fresh bone was weighed to obtain the wet bone weight. Mandible bone was weighed with the cranium, although the meat of each of these units was weighed separately. Brain tissue was recovered, but some tissue probably remained inside the cranium. Following Outram and Rowley-Conwy (1998), limb element results are averaged from both sides. All measures were taken with electronic scale to 0.5 g accuracy. Internal organs (except heart) and viscera were not weighed, though we estimated their weight by subtraction. Marrow could not be recovered because the skeleton had to remain unaltered after the experiment for later use as an anatomical specimen. Decomposition of remaining soft tissues (skeletisation) was completed naturally. Two months after the experiment bones were weighed again, and once more after six months without variation. These results were used for dry bone weights.

2.1 Indices calculated

We calculated three gross indices and a post-procurement return rate for BBD. We selected these indices because they are widely used in zooarchaeology and have been useful to model different butchery, transport and distribution scenarios. To avoid terminological ambiguity each index is defined.

The Meat Utility Index (MUI) or Meat Index (*sensu* Outram & Rowley-Conwy 1998), measures the gross yield of meat attached to each anatomical unit. Unlike Binford´s and Metcalfe and Jones´ MUI, which included meat, marrow and grease content in this index, we follow Outram and Rowley-Conwy (1998) and employ this as a real meat index. The MUI is calculated following the formula:

MUI= gross weight of part – wet bone weight

The General Utility Index (GUI) measures the general nutritive value of each unit, and it is calculated from the simplified formula proposed by Metcalfe & Jones for MUI:

GUI= gross weight of part - dry bone weight of part

Gross weight corresponds to the weight of each unit before being filleted, and dry bone weight is the weight of the same unit after complete skeletisation.

The Food Utility Index (FUI) was proposed by Metcalfe and Jones (1988) as a simplification of another Binford index, the MGUI (Modified General Utility Index). It is a transformation from the GUI developed to suit a specific butchery situation when several limb bones are transported together and as a consequence the transport probability of less useable bones (called 'riders') is increased by their proximity to higher value bones. This index has been criticised for obscuring variability since it might follow preconceived notions of utility (Madrigal 2004:193). The transformation occurs only in appendicular bones and involves raising the value of distal bones from higher utility proximal units including the scapula in the front leg and the femur in the rear leg. Following Metcalfe and Jones (1988), FUI was derived in two series, one for complete bones and another for proximal and distal portions.

Finally, the net yield or post-procurement return rate was calculated by simply dividing the MUI of each unit to the amount of time needed to extract the meat. All indices were standardised from highest value for each unit and/or segment following standard procedures for utility studies.

3 Results

Initial data on butchering units, total meat, bone, skin and organs weight are presented in table 1. Total live weight was 17,800 g. Eviscerated carcass weight was 11,209 g, 63% of the live weight, and was distributed slightly higher in axial skeleton (5,731 g *vs* 5,478 g). The meat fraction was 48.59% of live weight with 47.62% belonging to the axial skeleton and 52.38% to the appendicular portion. The specimen had no antlers.

Table 1 Butchery units and weight of meat, bones, skin and organs of Brown Brocket deer

Mazama gouazoubira CFA-12857	**Weight (g)**
Live weight	17,800
Butchering units	
Skull (with brain) + mandible (with tongue)	677.5
Chest	1,587.5
Forelimb	1,769
Hindlimb	3,709
Pelvis + sacrum	816.5
Vertebral column	2,649.5
Dressed weight (excludes skin, eyes, blood, viscera and organs)	11,209
Total meat	8,649
Total bones	2,425
Tongue	53.5
Eyes	32
Heart	166.5
Brain	81.5
Other organs, viscera and blood (approximate)	4,445.5
Skin	1,947

A sample of femur meat was processed in the Departamento de Química Orgánica, Facultad de Ciencias Exactas y Naturales (UBA). Results show BBD meat is lean, though with a good protein content (see table 2). The energy value is similar to impala (cf Ledger 1968 in Egeland & Bierly 2005: table 3).

Table 2 Nutritional content of a Brown Brocket deer brown meat sample

Nutritional information	
% Proteins	21.75
% Water	77.00
% Lipids	1.60
Energy	1.02 kcal/g

Table 3 Meat Utility Index (MUI) for Brown Brocket deer

Meat Utility Index (MUI)		
Anatomical unit	MUI	MUI (s)
Skull		
with brain	121.50	9.20
without brain	40	3.03
Mandible		
with tongue	120.75	9.14
without tongue	67.25	5.09
Cervical vertebrae	644.50	48.81
Thoracic vertebrae	600	45.44
Lumbar vertebrae	796.50	60.32
Ribs	1,310.50	99.24
Pelvis + sacrum	296.25	22.43
Scapula	331.50	25.10
Humerus	277	20.98
Radius + ulna	87.75	6.65
Metacarpal + carpals	0	0
Femur	1,320.50	100
Tibia + calcaneum + astragalus	248.50	18.82
Metatarsal + tarsals	0	0
Phalanges	0	0

3.1 *Meat Utility Index (MUI)*

MUI values are presented in table 3. We observed a distinct disparity between front leg and rear leg, with the femur as the unit with the highest proportion of meat. This is congruent with the typical morphology exhibited by cervids that prefer closed habitats, which present large hindlimbs adapted to short bursts of speed and transit in dense woods (Merino & Rossi 2010). No subcutaneous fat deposits were observed.

Filleting time was employed to build return rates (table 4). We are aware that return rates are far more variable than gross yields (see Madrigal & Holt 2002), even so this kind of information could be particularly useful for predicting part selection because it incorporates a measure of cost (cf Lupo 2006). The limited sample in this study forces us to be extremely cautious about the results. In the same vein, given that butchery was carried out with extreme care, observed times can only be considered as the maximum time needed to process meat. Return rates calculated here cannot be considered as 'real' post procurement return rates. Instead, they only represent an estimate of how easy or difficult it was to butcher each unit, and in this way they are useful to establish a new rank among elements different from MUI.

Return rates affect rankings based on gross yield (figure 1). The first units in the MUI ranking are femur, ribs, lumbar vertebrae, cervical vertebrae and thoracic vertebrae. The first units on return rates-based ranking are femur, lumbar vertebrae, thoracic vertebrae, scapula and humerus. One value was added by discounting intercostal meat, which weighs only 272 g but took considerable time to extract. If intercostal meat is not considered, then rib return rates rank second, but if it is considered then it falls to eighth place.

3.2 General Utility Index (GUI)

Table 5 presents the GUI values. Utility proportions do not change substantially, though the femur falls to second place. Not surprisingly, an unequal amount of food remained after initial meat processing. This distribution of this remnant GUI raises interesting implications for discussing potential transport related decisions:

1) 81.85% is on the axial skeleton

2) 66.43% of wet axial and 46.14% wet limb bones are still edible

3) appendicular residual GUI is mainly distributed on metapodials and phalanges (elements with no meat, which present all their utility in their

Table 4 Post-procurement return rate for Brown Brocket deer meat

Anatomical unit	MUI	Time (min)	Return rate (g/min)
Skull (with brain) + mandible (with tongue)	242.25	21.28	11.38
Cervical vertebrae	644.50	22.28	28.92
Thoracic vertebrae	600	3.40	176.47
Lumbar vertebrae	796.50	4.25	187.41
Ribs (with intercostal meat)	1,310.50	28.80	45.50
Ribs (without intercostal meat)	1,038.50	4.43	234.25
Pelvis + sacrum	296.25	10.53	28.15
Scapula	331.50	5.19	63.85
Humerus	277.00	2.66	104.20
Radius+ulna	87.75	1.63	54
Femur	1,320.50	5.03	262.35
Tibia	248.50	3.92	63.45

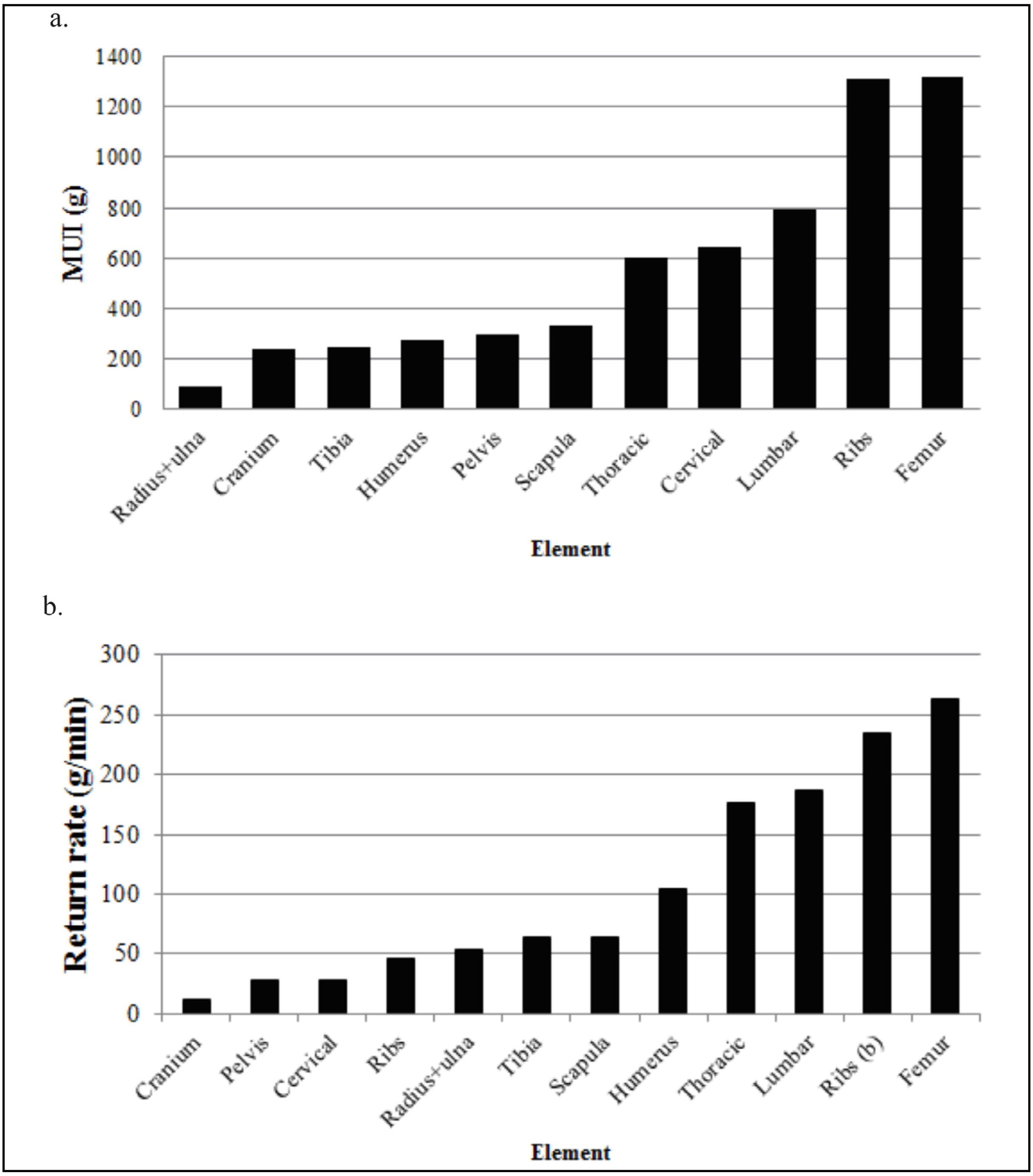

Figure 1 Gross yield (a) and return rate (b) for Brown Brocket deer meat. Note: Ribs (b): Value for ribs without intercostal meat

internal cavities), yet all axial units (specially the head) retain a significant amount of food

4) remnant GUI represents 18.63% of total axial GUI and 8.02% of total limb bones GUI

5) axial skeleton comprises 75.60% of the total wet bone, holding a significant quantity of food that remains inedible after meat butchering: 12.17% of total GUI.

In sum, axial bones are the heaviest, but also concentrate almost all the energy remaining after meat butchering, which represents an important amount of food. Conversely, limb bones retain less food, but they are also lighter (figure 2).

3.3 Food Utility Index (FUI)

Results for the FUI are shown in table 5 for complete bones and in table 6 for proximal and distal portions of long bones. Metcalfe & Jones (1988: tables 2, 3) consider the skull as a 'rider', and we follow the same criterion and generated two values for the skull + mandible; one considering it as a 'rider', and the other without doing that. However, although we made this

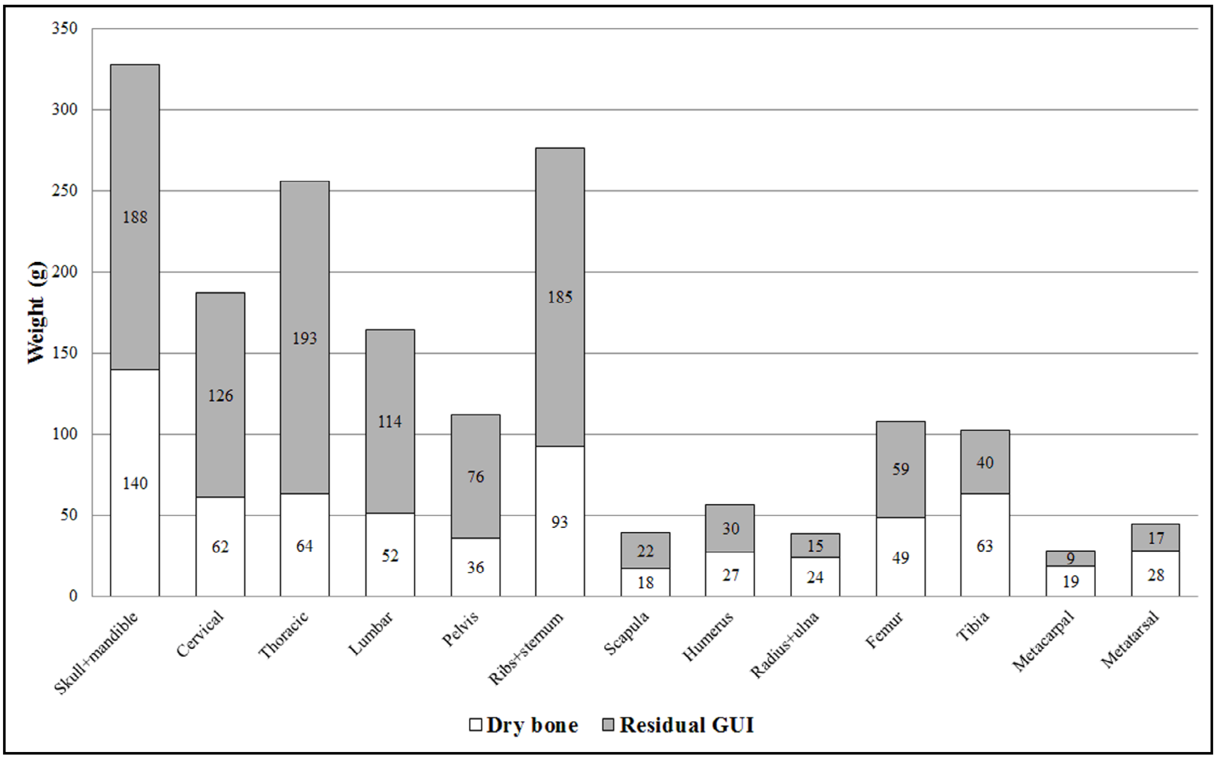

Figure 2 Residual GUI and dry bone weight in Brown Brocket deer wet bones

Table 5 General Utility Index (GUI) and Complete bones Food Utility (FUI) values for Brown Brocket deer

Anatomical unit	Weight (g)		GUI	GUI (s)	FUI Complete bones	FUI (s) Complete bones
	Meat + fresh bone	Dry bone				
Antler					1	1
Skull + mandible						
with tongue[1]	570.25	130	430.25	28.78	430.25	28.78
with tongue[2]					215.63	14.42
without tongue[1]	516.75	130	376.75	25.20	376.75	25.20
without tongue[2]					188.88	12.63
Cervical vertebrae	832	61.50	770.50	51.54	770.50	51.54
Thoracic vertebrae	856	63.50	792.50	53.01	792.50	53.01
Lumbar vertebrae	961.50	51.50	910	60.87	910	60.87
Ribs + sternum	1,587.50	92.50	1,495	100	1,495	100
Pelvis + sacrum	408.25	36	372.25	24.90	372.25	24.90
Scapula	370.75	17.50	353.25	23.63	353.25	23.63
Humerus	334	27.25	306.75	20.52	330	22.07
Radius + ulna	126.50	24	102.50	6.86	216.25	14.46
Metacarpal + carpals	28	18.75	9.25	0.62	112.75	7.54
Fore phalanges	4.21	1.33	2.88	0.19	57.82	3.87
Femur	1,428.75	49	1,379.75	92.29	1,379.75	92.29
Tibia + calcaneum + astragalus	351.50	63.25	288.25	19.28	834	55.79
Metatarsal + tarsals	44.50	27.75	16.75	1.12	425.38	28.45
Hind phalanges	4.96	1.63	3.33	0.22	214.35	14.34

[1] Values not considering cranium as 'rider'. Cranium includes brain.[2] Values considering cranium as 'rider'. Cranium includes brain.

adjustment to make the index comparable with other utility studies, we believe it would not be useful in this case, given the small size of the antlers of BBD.

4 Expanding the utility: BBD & other artiodactyls

We present results of correlation coefficients between BBD utility indices and available for larger cervids: White-Tailed deer (35-135 kg), huemul (55-90 kg) and caribou (80-180 kg). In order to expand our data base, we also added values for two <60 kg biomass bovids: impala (Lupo 2006) and sheep (Binford 1978). We employed total values, not the standardised series, following both Metcalfe and Jones (1988) and Madrigal (2004), who suggest this procedure is not desirable (but see Outram & Rowley-Conwy 1998:846).

Table 6 Food Utility Index (FUI) for Brown Brocket deer considering proximal and distal segments for limb bones

Mazama gouazoubira Food Utility Index (FUI)		
Anatomical unit	FUI	FUI (s)
Antler	1	1
Skull + mandible		
with tongue[1]	430.25	28.78
with tongue[2]	215.63	14.42
without tongue[1]	376.75	25.20
without tongue[2]	188.88	12.63
Cervical vertebrae	770.50	51.54
Thoracic vertebrae	792.50	53.01
Lumbar vertebrae	910	60.87
Ribs + sternum	1,495	100
Pelvis + sacrum	372.25	24.90
Scapula	353.25	23.63
Proximal humerus	353.25	23.63
Distal humerus	330	22.07
Proximal radius + ulna	216.25	14.46
Distal radius + ulna	159.38	10.66
Carpals	84.31	5.64
Proximal metacarpal	46.78	3.13
Distal metacarpal	28.02	1.87
Fore phalanges (1° + 2° + 3°)	15.45	1.03
Proximal femur	1,379.75	92.29
Distal femur	1,379.75	92.29
Proximal tibia	834	55.79
Distal tibia	561.13	37.53
Calcaneum	288.94	19.33
Astragalus	288.94	19.33
Tarsals	288.94	19.33
Proximal metatarsal	152.84	10.22
Distal metatarsal	84.80	5.67
Hind phalanges (1° + 2° + 3°)	44.06	2.95

[1] Values not considering cranium as 'rider'. Cranium includes brain.[2] Values considering cranium as 'rider'. Cranium includes brain.

Brown Brocket deer MUI was compared to huemul, White-Tailed deer and impala (caribou and sheep meat values are not available). In the case of White-tailed deer, we correlate two series, one developed by Madrigal and Holt (2002) and the other one by Jacobson (2000, in Madrigal 2004). Both series differ in the criteria employed to process some units: Madrigal and Holt (2002) considered the location of the muscle packages and Jacobson (2000, in Madrigal 2004) made the cut in the exact limit of the bone (criteria also employed by us). We also made some adjustments in our index to assure comparability with huemul and White-Tailed deer series: original huemul series from Belardi and Gómez Otero (1998), accounted separately for ribs and sternum, and we treated them as a single unit. Head and mandible meat was not considered for huemul and White-tailed deer comparisons because neither set included data from those units.

Results indicate a strong and positive relationship with all species (see table 7). Four of the five higher MUI units are the same: femur, ribs, thoracic vertebrae and cervical vertebrae.

Although we know return rates might be more variable than gross yields, we also compared post-procurement return rates derived from meat processing between BBD, White-Tailed deer and impala. We found a high correlation between BBD and impala MUI return rates, but no correlation was found with the average nor between each of the three individuals processed by Madrigal and Holt (2002). These authors also found no correlation among them, therefore the absence of correlation between BBD and White-Tailed deer could not be related to interspecific variability.

In the same vein, if we pay attention to the five higher return units of the three species, only two elements are repeated across the three species: thoracic vertebrae and femur. BBD and impala repeat in three cases: femur, thoracic vertebrae and humerus; and four elements match with White-tailed deer results from the three individuals processed by Madrigal and Holt (2002): femur and thoracic vertebrae (with the three samples), scapula (with two samples), and lumbar vertebrae (with one sample). These data suggest return rates are more variable than gross yields, and that butchering speed or processing preferences might be important key factors in building this kind of data (see also Madrigal & Holt 2002:750).

Brown Brocket deer GUI was compared to huemul, caribou, impala and sheep (GUI values for White-tailed deer are not available), showing strong, significant correlations (see table 6). We observed many repetitions among the top five elements. Femur, ribs and thoracic vertebrae are among the first five ranked in all cases. The pelvis is also among the first five ranked in all but the BBD series. Caribou, BBD and one sheep series share skull ranks, and impala, huemul and one sheep series share cervical vertebrae among the five top ranked units.

In order to evaluate if remaining food proportions are consistent between different body sizes, we also correlated BBD residual GUI with that of impala, the only taxon with dry and wet bone weight data. In this case, we compared three measures: 1) residual GUI gross weight; 2) %residual GUI/element GUI; and 3) %residual GUI/wet bone weight. In all three cases, correlations between BBD and impala residual GUI are positive, suggesting quite similar proportions of food remain in wet bone after meat butchering between individuals of different body size (table 8).

Table 7 Correlation values between economic utility indices for Brown Brocket deer and larger-size artiodactyls

TAXON	Sample dressed weight (kg)	MUI		Return rate		GUI		FUI			
								Complete bones		Portions	
		r	NC	R	NC	r	NC	r	NC	r	NC
White-tailed deer	36.7[1]	0.73[1]**	10	0.20	10	na		na		na	
	24.1-57.9[2]	0.83[2]*		na		na		na		na	
Huemul[3]	30.44	0.91*		na		0.91*	10	0.89*	10	na	
Caribou[4]	60.71	na		na		0.92*	14	0.90*	14	0.94*	24
Impala[5]	49.75	0.67**	11	0.79*	11	0.80*	15	0.74*	15	0.84*	25
Sheep[6]	14.24	na		na		0.80*	15	0.74*	15	0.80*	25
	24.73	na		na		0.82*	15	0.76*	15	0.80*	25

* $p < 0.01$
** $p < 0.05$

[1] Data from Madrigal and Holt (2002: table 1). Dressed and meat weight is averaged from 3 individuals ranging 18.6 kg - 54.3 kg.
[2] Data derived from meat gross yield in kcal (Jacobson 2000, in Madrigal 2004: table 1) and converted to weight from White-tailed deer meat kcal value (6.09 kcal/g; cf. McCullough and Ullrey 1983 in Madrigal and Holt 2002:748). Average dressed weight not available. Meat weight is averaged from 5 individuals.
[3] Data from Belardi and Gómez Otero (1998: tables 1, 2 and 3).
[4] Data from Metcalfe and Jones (1988: tables 1, 2 and 3) and Binford (1978: table 1.2).
[5] Data derived from Lupo (2006: table 1). Weight informed is the average live weight from two individuals.
[6] Data derived from Binford (1978: tables 1.1 and 1.2).

Table 8 Correlation values between residual GUI of Brown Brocket deer and impala

	Gross residual GUI[1]	Residual GUI/ element GUI[1]	%residual GUI/ wet bone weight[1]
BBD *vs* impala (NC=15)	0.82	0.98	0.80

[1]Impala data from Lupo (2006: table 1)

Finally we compared BBD FUI values with huemul, caribou, impala and sheep (two series). We correlated two series, one for complete bones and the other for proximal and distal portions of the limb bones. This last series is not available for huemul given no GUI values were presented for metapodials and phalanges by Belardi and Gómez Otero (1998). To facilitate comparability with caribou, head values in BBD series are based on skull+mandible without the tongue (following Metcalfe and Jones 1988: tables 2, 3). As occurred with previous results, BBD FUI values covary strongly with all considered indices (see table 7).

5 Conclusion

Decision making related to butchery, transport and consumption is a very complex process which involves multiple variables and assessing particular characteristics for each prey speices, though in general terms hunter-gatherers tend to maximiSe the amount of food obtained after a successful hunt (Lupo 2006 among others). Taking this into account, this work was primarily focused on developing several frames of reference useful to interpret fossil assemblages of an important food resource for Neotropical hunter-gatherers, namely medium and small sized cervids.

The results indicate a close fit between all gross yield indices of BBD and larger sized and/or adapted to more open environments artiodactyls. Even though there could be substantial nutritional variability depending on environmental parameters (cf Speth 1990), and that more samples are still required to cover this issue, we can propose consistency in economical anatomy at least among artiodactyls from

18-180 kg live weights. A similar suggestion has been also made by Binford (1978:23) when comparing sheep and caribou meat indices, though he noted that some interspecific differences could affect transport and butchery decisions (see Binford 1978: figure 1.1).

Finally, Lupo (2006) has argued that among utility indices the gross yield might not be a good predictor of bone transport potential. As a consequence, zooarchaeologists might be employing a unit of measure with little value in terms of understanding human behaviour (Lupo 2006). This has in part been recognised by constructing alternative indices like the MGUI-FUI, which modify the ranking of some units because they are transported as

'riders' of higher value bones. From an optimal foraging perspective, a possible and meaningful solution to this dilemma could be to integrate gross utility values with more information about post-procurement costs. This could be made by developing new indices based on net return rates and also by gathering more data about cost/benefit ratios of field processing versus transport of units with differing processing time and residual utility (Lupo 2006). These kinds of measures might help us to understand the complex array of decisions behind resource processing and transport strategies, but they are at present only available for two artiodactyls (impala and partially White-Tailed deer). At this point, even though we found a strong correlation between BBD and impala meat return rates, variability observed experimentally suggests processing times could be influenced by taxon and/or operator specificities. More comparative data are needed before robust inferences can be drawn. In the same vein, the strong similarities observed between different measures of remnant utility of BBD and impala points to this variable as a good proxy measure of transport cost to be explored in the future on larger sized species.

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