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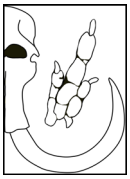

Body-mass estimation from Middle Pleistocene fallow deer of Europe

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Bullet-Points Abstract

- Analysis of a sample covering a period of time ranging from 700,000 to 250,000 years ago.
- Body mass comparison between fallow deer species of the Middle Pleistocene.
- Comparison of the overall averages obtained for each site considered.
- Considerations on the correlation between size variability and climatic situation.

Introduction

The size variability in the mammals is considered by many scholars an important tool to investigate their response to climatic changes (among others Lister et al., 2010; Van Asperen et al., 2012; Mecozzi & Bartolini Lucenti, 2018). Moreover, fluctuations in size or reduction trend in mammals represents a great tool for the biochronology (e.g., Van Asperen, 2010; Brugual & Boudadi-Maligne, 2011). Ecological factors that can influence the body size of mammals include climate (mainly mean annual temperature and seasonality), population density and interspecific competition (Geist, 1971; 1987; Lindstedt & Boyce, 1985; Weinstock, 1997). These factors tend to induce the increase of the body size in populations inhabiting region affected by cold conditions (Weinstock, 1997). Particularly, climate can produce demographic effects on the populations. In fact, more severe winters, for example, cause a strong decrease of the food supply and lead to a higher mortality rate (Weinstock, 1997). As a consequence, during the following growth season the intraspecific competition decreases (Guthrie, 1984). The reductions of competition in turn, led a higher quality and quantity of food resources, giving rise the development of a larger body size (Weinstock, 1997). Considering this, the relation between body size and climatic conditions appears to be valid, which leads the large size during the glacial stage and the small size during the interglacial one.

Among cervids, a preliminary analysis of *Cervus elaphus* Linnaeus, 1758 samples from Late Pleistocene Italian sites was conducted by Di Stefano et al. (2015). The authors stated that the sample from MIS 2 (Marine Isotope Stage) of the northern Italy was of a large size, larger than the contemporaneous ones from central and southern Italy and from early interglacial and glacial stages (MIS 5-3). Larger body proportions in glacial specimens was also recognized from Steele (2002), who also documented the smallest size in the sample referred to MIS 5. Nevertheless different results were reported by Van der Made et al. (2014) for a large dataset from Middle to Late Pleistocene European sites. His results showthat samples from interglacials were larger than glacial ones, and, in addition, the samples from MIS 7 are larger in size than earlier (MIS 9) and later (MIS 5) ones.

Today the genus *Dama* is composed by two species: *Dama dama* Linnaeus, 1758 and *Dama mesopotamica* Brooke, 1875. The extant *Dama dama* is widespread in the western Palearctic, whereas in the Middle East *D. mesopotamica* occurs. The fallow deer is a highly plastic species, inhabiting a wide range of habitats, including forest, scrubland and grassland (Masseti & Mertzanidou, 2008) . Based on the features of the antler of the fossil specimens from the Middle Pleistocene of Europe, several species of fallow deer have been proposed. Recently, *Dama roberti* Breda & Lister, 2013, a new species of palmated fallow deer, was described by Breda & Lister (2013). This taxon possesses distinct antler morphology, with a narrow palmation ending in a single terminal point very different from later species, *Dama clactoniana* Falconer, 1868 and extant *D. dama*, which display a strongly palmated antlers and a second tine (sometimes also a third tine in *D. clactoniana*) above the basal one. In the European fossil record, the Clacton fallow deer occurs in the late Middle Pleistocene (Fontana Ranuccio Faunal Unit, 0.458 Ma), and their remains were recognized in Britain, Italy, France and Spain (Breda et al., 2015; Strani et al., 2018).

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Species	Site	MIS	Reference	M^2	M_2
Dama roberti	Pakefield	MIS 17	(Stuart & Lister, 2010)	57.7	65.1 (max= 67.1 - min= 63.1; n= 2)
Dama roberti	West Runton	MIS 17-15	(Stuart & Lister, 2010)	55.0	55.7 (max= 59.4 - min= 53.3; n= 8)
Dama roberti	Soleilhac	MIS 17-15	(Lacombat, 2005)		53.3 (max= 57.6 - min= 49.3; n= 4)
Dama cf. *roberti*	Isernia La Pineta	MIS 15	(Strani et al., 2018)	59.5	60.9
Dama roberti	Valdemino	MIS 14	(Breda, 2015)		58.8
Dama cf. *roberti*	Contrada Monticelli	MIS 15-13	(Mecozzi et al.2017; Stefanelli et al. 2019)	64.1 (max= 64.1 - min= 64.1; n= 2)	51.7 (max= 53.3 - min= 49.3; n= 3)
Dama clactoniana	Fontana Ranuccio	MIS 12	(Biddittu et al., 1979; Segre & Ascenzi, 1984)	60.7 (max= 65.0 - min= 55.6; n= 7)	
Dama clactoniana	Riano	MIS 9	(Bonadonna, 1965)	61.7	64
Dama dama	Modern	MIS 1	(Di Stefano, 1994)	52.4 (max= 54.4 - min= 50.7; n= 3)	53.5 (max= 57.8 - min= 50.2; n=4)

Tab. 1. Table of the averages of M^2 and M_2 of fallow deer from the Middle Pleistocene and modern.

Here, we present the body-mass estimation of two fallow deer, *D. roberti* and *D. clactoniana*, for the investigation of possible changes through the Middle Pleistocene as a response to climatic fluctuations and/or possible evolutionary trend.

Material and Methods

The fossil material studied comes from Contrada Monticelli (Castellana Grotte, Bari) that is currently preserved at the Museum of Earth Sciences of the University of Bari. The material consists of four craniodental findings: 30685, left jaw with P^3-M^3; 3066, right hemimandible with P_3-M_3, left with P_4-M_3 and right maxillary with M^1-M^2 (catalog number 30660); 30674, left hemimandible with P_4-M_3; 30659, splancnocranium with mandible. The material of *D. clactoniana* from Melpignano and San Sidero, stored at PaleoFactory Laboratory, Department of Earth Science, Sapienza (University of Rome) is taken into account for comparison. We built our dataset, collecting the measurements of M^2 and M_2 of the fallow deer from the Middle Pleistocene of Europe. The data of the extant fallow deer (*Dama dama*) were obtained by Di Stefano (1994). Body-mass estimation was calculated following Janis (1990). According to Janis (1990), the estimation of the body-mass in Artiodactyla based on both upper and lower first molar and third molar is unreliable, underestimating and overestimating the weight respectively. Therefore, the estimation of the body-mass was performed on the values of M^2 and M_2 (Tab. 1).

Results and Discussions

A series of well-known fossil samples has been selected, all having a more or less abundant presence of fallow deer and covering a time span ranging from 700,000 to 250,000 years ago (Fig. 1). The most ancient samples, coming from Pakefield, West Runton, Soleilhac, Isernia La Pineta, Contrada Monticelli and Valdemino, belong to *Dama roberti* (or *Dama* cf. *roberti*), the deer species recognized during the early Middle Pleistocene. The body-mass estimated for the samples coming from these sites shows how Pakefield (MIS 17), the oldest, records measure larger than those from the other localities (Tab. 1). Whilst, a slight decline in the average dimension is observed both in Soleilhac (MIS 17-15) and West Runton (MIS 17-15) (Tab. 1). In particular, the values from Soleilhac fall in the variability of the extant fallow deer (Tab. 1). Contrada Monticelli (MIS 15) presents a huge variability of the body-mass estimation, with the largest value in the M^2 and the smallest in M_2 (Tab. 1). The samples from Isernia La Pineta (MIS 15) and Valdemino (MIS 14) show similar values, both larger than those from Soleilhac and West Runton. The samples coming from Valdarno-Notarchirico, Fontana Ranuccio, Riano, San Sidero and Melpignano, belong instead to *Dama clactoniana*. The body-mass estimated for these localities is quite constant, except for the larger value of M_2 from Riano (MIS 11) and the lower value of M_2 from Venosa-Notarchirico (MIS 12) (Tab. 1). The overall values of *D. clactoniana* are similar to those of *Dama* cf *roberti* from Isernia La Pineta and *D. roberti* from Valdemino (Tab. 1). Finally, both fossil fallow deer, *D. roberti* and *D. clactoniana*, are larger than the extant *D. dama* (Tab. 1).

According to Mazza & Bertini (2013), the large mammals are significantly affected by the severe

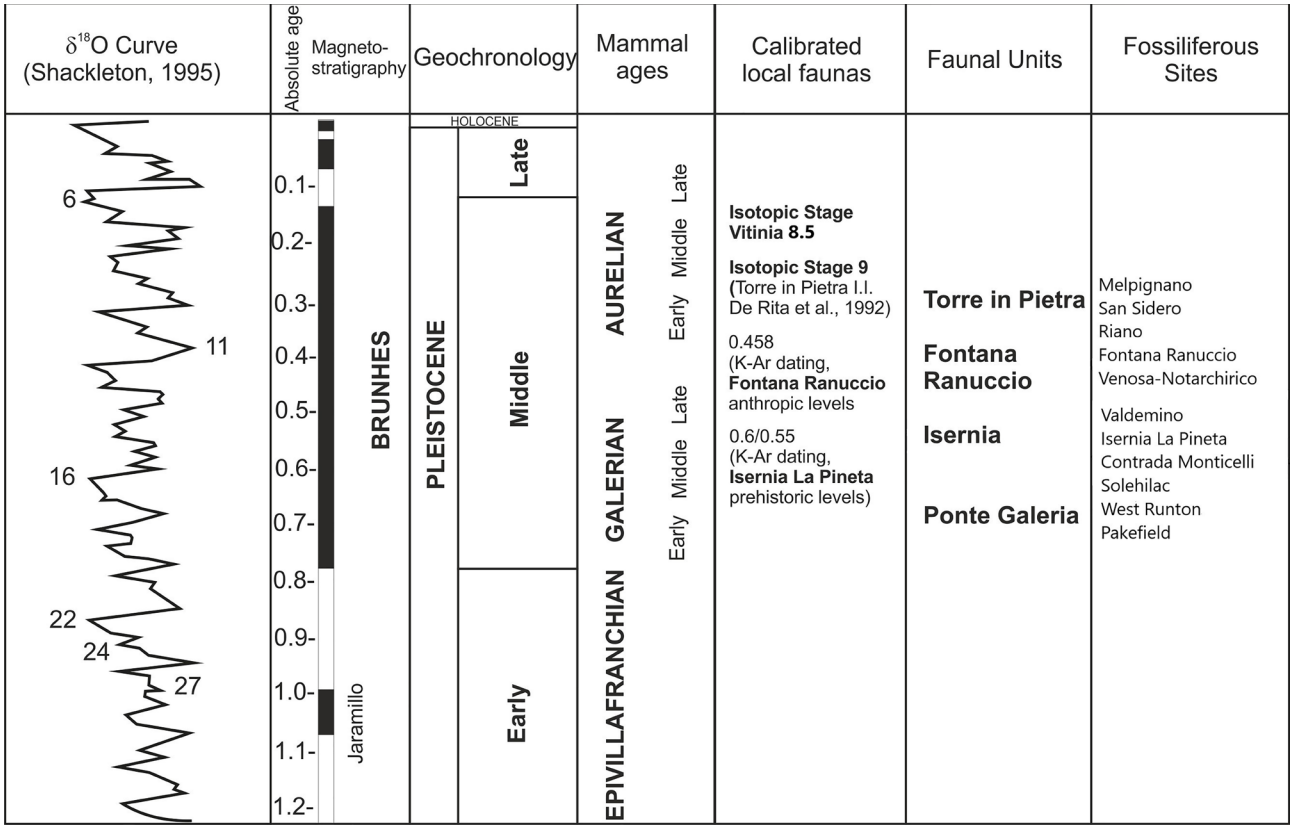

Fig. 1. Biocronological scheme of the fossiliferous sites discussed in the text.

Pleistocene climatic fluctuations. Food stress derived from climate change can affect the size of herbivores such as reindeer by placing a limit on the size (Weinstock, 1997), especially where there is a shift from a condition of greater abundance of vegetation, typical of interglacial times, to a condition of relative scarcity, typical of glacial periods. In the case of omnivores, as in wild boars, and carnivores, as in wolves and foxes, an increase in size has been instead found related to a decrease in temperatures (Davis, 1981). In the case of the sample examined for this study, it is possible to observe that there is no substantial difference in size between the two Pleistocene species *D. roberti* and *D. clactoniana*; vice versa, they are larger on average than the extant species *D. dama*. The largest dimensions both in *D. roberti* and *D. clactoniana* have been found in the sites respectively of Pakefield and Riano, both correlated to during interglacial phases. On the contrary, from West Runton and Soleilhac, the reduction of the body-mass could suggest a decrease in size probably linked to cold climatic conditions. In Italian record, no differences can be detected among the samples of *D. roberti*, since the values for the material from interglacial and glacial stages are closer. In the considered samples of *D. clactoniana,* the body mass is quite constant throughout the late Middle Pleistocene.

The large size during interglacial stages in fossil fallow deer was also reported by Van der Made et al. (2014), which detected similar patterns in *Megaloceros giganteus* Blumenbach, 1799 and *C. elaphus*. In this scenario, the fluctuation of body mass in Middle Pleistocene fallow deer of Europe contrasts with what generally supposed on size variation as response to climate. A possible interpretation of this body-mass fluctuation could be the result of a mix between ecological factors and climate. In fact, the fallow deer inhabit a wide range of habitats, including forest, scrubland and grassland, prefers temperate climatic conditions. Despite the high competition during the interglacials, the paleoenvironmental framework was favorable for the diffusion of this taxon, with higher quality and quantity of food resources. The increase of food supply could result in the development of a larger body size. Furthermore, the large size in herbivore taxa from Europe in glacial stages was recognized only during the Last Glacial (MIS 2, Late Pleistocene), for instance in *C. elaphus* (Steele, 2002; Van der Made et al., 2014; Di Stefano et al., 2015;). By the start of Middle Pleistocene, the Last Glacial was the more intense glacial episode, with a strong impact on mammal assemblage. Probably, rather than a high quality and quantity of food resources, the large size during the Last Glacial recognized in

cervid fossil sample of Europe could be a consequence of a reduction of the demographic pressure in relation to a higher mortality rate (Weinstock, 1997).

Conclusion

The estimation of the cervid *Dama* body-mass in Middle Pleistocene is here performed for the first time. No difference can be detected between the Middle Pleistocene taxa, *D. roberti* and *D. clactoniana,* whereas these fossil species are larger than extant *D. dama*. These results suggest that the body-mass in the specimens from interglacial stages was larger than those from glacial ones. The size fluctuation in Middle Pleistocene fallow deer was related to favorable paleoenvironmental condition, with high quality and quantity of food resources, that in turn were controlled by climatic conditions.

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