Biodiversity Journal, 2019, 10 (3): 269–274 https://doi.org/10.31396/Biodiv.Jour.2019.10.3.269.274

Craniometrical studies on the skull of the wild rabbit, *Oryctolagus cuniculus* (Linnaeus, 1758) (Mammalia Leporidae), in the Maltese archipelago

Ian Falzon

Centre for Agriculture, Aquatics and Animal Sciences, Institute of Applied Sciences; Malta College of Arts, Science and Technology (MCAST), Qormi, Malta; email: Ian.Falzon@mcast.edu.mt

ABSTRACT The aim of this study is to establish the craniometric data of the rabbit species found on Malta and therefore establish parameters for the anatomical identification. Twenty-eight crania of adult *Oryctolagus cuniculus* (Linnaeus, 1758) (Mammalia Leporidae) were used to establish 15 average indexes. These indexes illustrated a pronounced wedge-shaped head. The Orbital vertical diameter was also considerable, allowing for a very large oculus. Environmental factors could be responsible for this adaptation.

KEY WORDS *Oryctolagus cuniculus*; Malta; lagomorph; morphology.

Received 05.07.2019; accepted 10.09.2019; published online 30.09.2019

INTRODUCTION

Although the wild rabbit has been featured in many publications on Maltese Fauna, it has never been given individual attention and basic identification criteria have never been published. Taxonomic data of the European rabbit, *Oryctolagus cuniculus* (Linnaeus, 1758) (Mammalia Leporidae), found on the Maltese islands is insufficient and the books and papers which refer to it simply conclude that the rabbit found in Malta is the same as that found in other parts of Europe and the Palaearctic region.

The aim of this study is to establish the craniometric data of the rabbit species found on Malta, therefore establishing parameters for the anatomical identification.

The Rabbit Cranium

Like the rabbit's entire skeleton, the skull is very delicate and light when compared to the skeleton of other mammals.

The oral cavity is long and carved. All the teeth are open-rooted and grow continuously throughout life. This is because they are adapted to be worn down by hard or fibrous food materials. The dental formula is: I 2/1, C 0/0/ PM 3/2, M 3/3 x2 =28 total.

The incisors have enamel only on the outer surface, which wears more slowly than the inner surface, creating the characteristic chisel shape needed for nibbling plant material. In the upper jaw, the second pair of incisors is vestigial pegs and is found behind the first large pair. There are no canine teeth and the space between the incisors and the cheek teeth is known as the diastema. The premolars and molars (cheek teeth) are flattened teeth for grinding food. The jaw moves in a circular fashion to force the food against their roughened surfaces. The lower teeth grow at a faster rate than the upper teeth (Aspinall & O'Reilly, 2007). This growth is of about 2mm per week. The incisors help to slice the food, which is then chewed to a bolus by the action of the cheek teeth, which along with the tongue move the bolus caudally so that all teeth get equal chewing action.

The eye orbits are laterally situated with prominent globes. This way the rabbit can obtain almost 360° vision by tilting the head and moving the eyes slightly. The orbit is circular and made of bone apart from the lower rim where it is walled by the muscles of mastication (O'Malley, 2007).

MATERIALS AND METHODS

A total of 28 *Oryctolagus cuniculus* skulls from Malta were used for this study.

The skulls were in natural decomposition or they were obtained from naturally dead or hunted specimens. They were cold water macerated.

Initially, they were skinned and all the meat that could be removed was cleaned using a scalpel blade. They were then placed into a plastic recipient and covered with water - kept at room temperature - until most of the remaining flesh had fallen off. The maceration process took approximately one month. Fly larvae were the main decomposers in the process.

After maceration was complete, they were bleached lightly using 3% Hydrogen Peroxide and left to air-dry. Bleach was poured on the heads carefully in order to ensure that all tight grooves were cleaned. This process was done in about 30 seconds to prevent Hydrogen Peroxide from eroding the skull. Once dry, they were checked and any loose parts were secured in place using colourless glue. This process follows the recommendations of the University of Arizona Cooperative Extension (2000) for the preservation of skulls for scientific research. The advantage of using cold water-maceration to clean the skull is that the skull is not damaged and does not shrink as in the case of boiling. This is the best option for skulls used for scientific research. Disadvantages include bad odour, long times due to its slow process and falling out of loose parts such as teeth that must be re-assembled. A total of 15 craniometric indices were measured in each skull and were adapted from Jaksic & Scoriguer (1981), Monnerot et al. (1994), Sharples et al. (1996), Baldacchino & Schembri (2002), Yahaya et al. (2012), Szuma (2008), Endo et al. (2002), and van der Geer et al. (2010). The landmarks of each measured index are explained and illustrated below (Figs.1–4). Abbreviations are used for simplification.

1. Occipitonasal length (OCC) (Fig 1.)
2. Orbital vertical diameter (maximum) (OBVD) (Fig 1.)
3. Condylobasal length (CON) (Fig 2.)
4. Zygomatic width (ZYG) (Fig 2.)
5. Diastema length (DIA) (Fig 2.)
6. Maxillary tooth row length (MTR) (Fig 2.)
7. Palate length (PL) calculated by adding DIA to MTR
8. Diastema-tooth row ratio (DTR) DIA:MTR ratio.
9. Mandibular tooth row length (MDT) (Fig 3.)
10. Mandible length (MDL) (Fig 3.)
11. Height of mandible at M1 (HM1) (Fig 3.)
12. Total posterior mandible height (TPMH) (Fig 3.)
13. Nasal length along the mid-line (NL1) (Fig 4.)
14. Nasal length on the side (NL2) (Fig 4.)
15. Inter-orbital Width (IOW) (Fig 4.)

All characters were measured in millimetres, except DTR, which is a ratio. Values for each measurement were expressed as means ±standard deviation. Measurements were taken using a pair of digital Vernier callipers and were recorded to the nearest 0.01mm. The Vernier Callipers used had a repeatability of 0.01mm and an accuracy of 0.02 mm. Measurements were taken thrice for each head to verify the measurement.

Due to the occasional absence of mandibles and occipital parts, some of the skulls have fewer data in this section. Any skull with deformity and/or condylobasal length smaller than the mean value - 2 standard deviations for a group - were excluded to prevent any data distortion due to age, although due to the rapid growth rate exhibited by rabbits, age effects are unlikely (Taylor et al., 1977). Rabbits are not considered to be sexually dimorphic (Sharples et al., 1996) and therefore the samples were considered as 1 data set.

RESULTS

Data collected is represented in Table 1. Group means for each index are presented; ±standard error for all characters is also given. All indexes are presented in mm except DTR which is a ratio.

The Occipitonasal measurement was high while the Zygomatic index was narrow. This gives the Maltese *Oryctolagus cuniculus* the pronounced wedge-shaped head. The Orbital vertical diameter was also considerable, allowing for a very large oculus. Nasal length (NL2) comprised almost half of the Occipitonasal length in all specimen.

DISCUSSION

The measurements have yielded unexpected results. In fact, the cranial dimensions from the rabbits in Malta are not similar to the same values from populations in the same latitudinal range as Malta, namely North Africa.

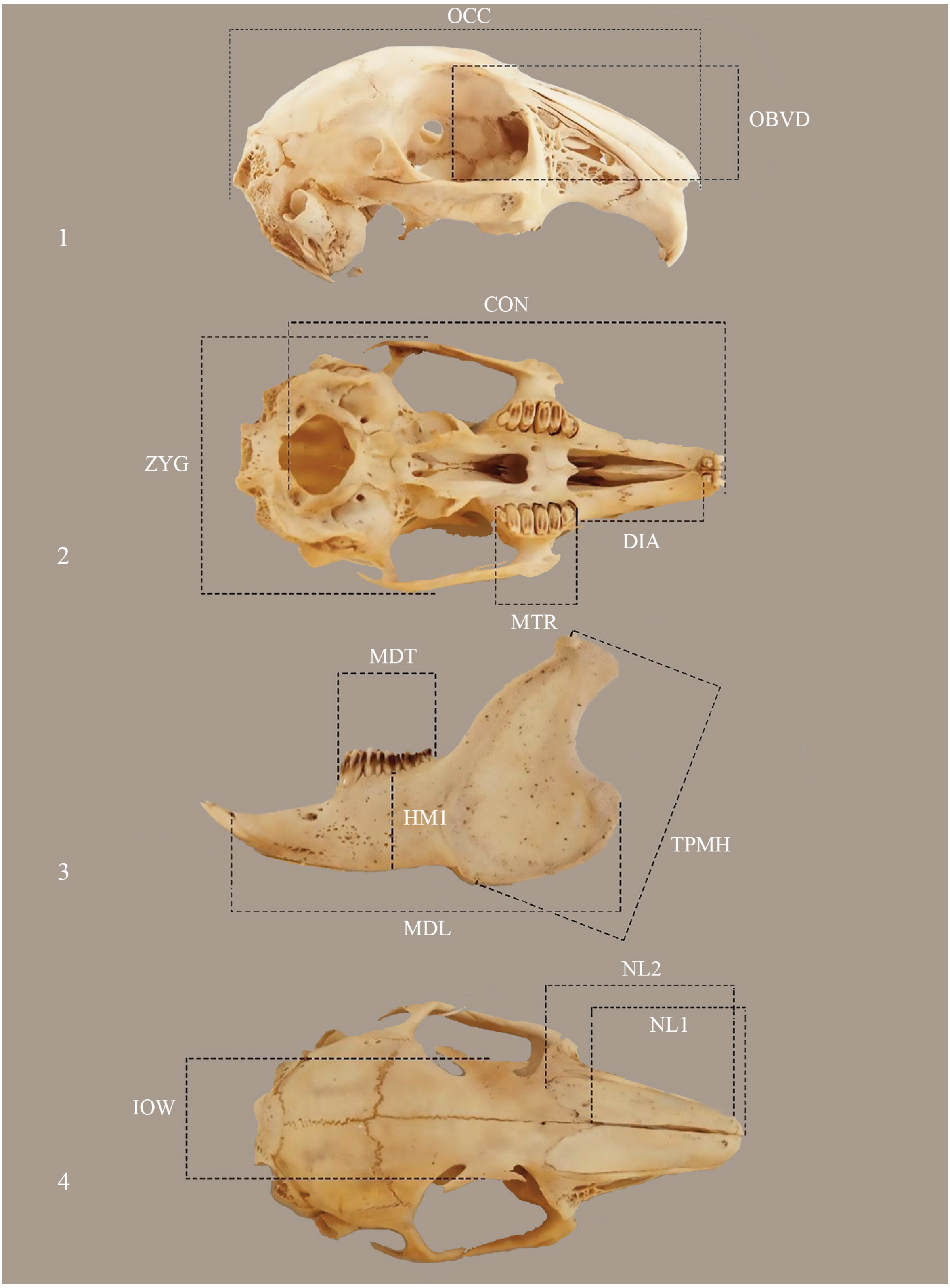
This is because when comparing the measurements for Malta to the measurements collected by Sharples et al. (1996), it is evident that the Maltese rabbits have large occipitonasal length. The Maltese mean measurement for occipitonasal length stands at 74.43 mm. While Bergmann's rule states that Maltese indexes should be close to those on the same geographic latitude (Meiri & Dayan, 2003; Lin et al., 2008), the North African occipitonasal length has an index of 72.4 mm. This trend is also evident in the condylobasal index. Standing at 66.85 mm for Malta, they are more akin to measurements of South and North France (65.5–67.4 mm) than North Africa (64.2 mm).

On the other hand the Maxillary diastema length, Palate length, Diastema: tooth row ratio, Zygomatic width and Mandible length for the Maltese populations have measurements which are found to be similar to the indexes presented by Sharples et al. (1996) for North Africa. This indicates that the Maltese *Oryctolagus cuniculus* has developed a particularly narrow and long head.

The longer head seems to contradict Foster's rule (Foster, 1964). However, if, as it has often been suggested, these rabbits have been introduced by the Romans (Fitter, 1959), the founding stock could

Measurement	Mean (in *mm*)	Std. Error
1. Occipitonasal length *(OCC)*	74.43	±0.83
2. Orbital horizontal diameter (maximum) *(OBHD)*	18.18	±0.18
3. Condylobasal length *(CON)*	66.85	±0.76
4. Zygomatic width *(ZYG)*	36.31	±0.26
5. Diastema length *(DIA)*	19.59	±0.39
6. Maxillary tooth row length *(MTR)*	13.58	±0.26
7. Palate length *(PL)*	33.18	±0.45
8. Diastema-tooth row ratio *(DTR)*	1.45	±0.03
9. Mandibular tooth row length *(MDT)*	13.8	±0.16
10. Mandible length *(MDL)*	50.49	±0.66
11. Height of mandible at M1 *(HM1)*	11.46	±0.11
12. Total posterior mandible height *(TPMH)*	31.74	±0.43
13. Nasal length along the mid-line *(NL1)*	25.17	±0.36
14. Nasal length on the side *(NL2)*	32.15	±0.44
15. Inter-orbital Width *(IOW)*	17.22	±0.22

Table 1. Group means and standard errors for all characters.
All characters are measured in mm, except DTR, which is a ratio.



Figures 1-4. *Oryctolagus cuniculus* skull from Malta: lateral view (Fig. 1), ventral view (Fig. 2), mandible (lateral view) (Fig. 3), dorsal view (Fig. 4).

have been of a larger, domesticated variety that narrowed gradually.

It is possible that isolation and environmental factors in the Maltese islands have led the rabbits to adopt a narrower shape.

Shelter available in the local habitats, namely garrigue and rocky terrain, make it advantageous for rabbits to have a narrow head. The association between the form of the skull and behaviour such as burrowing has been shown (e.g., Gans, 1974; Hopkins & Davis, 2009; Barros et al., 2011; Sherratt et al., 2014).

The rabbit is a burrowing animal by nature, building nests underground. Garrigues, cliffs and boulder screes offer little opportunity for the rabbit to dig burrows as they only harbour shallow soil pockets. Thus, as it has been observed, the rabbit will often make do with crevices in the rocks themselves. Considering all this, it is evident how much more convenient for the rabbit is to have a body shape which can fit in narrow crevices and thus enable it to hide easily. Small bodies also allow the rabbit to escape from minute apertures in the same stony shelter. Consequently, this could be the reason for the elongated shape of the head in the Maltese rabbit.

In a study conducted by van Heteren et al. (2014, 2015), it is suggested that cave bears (*Ursus spelaeus* (Rosenmüller, 1794) from Moravský Kras and Merkensteinhöhle have a relatively long maxilla and a narrow cranium. Their reason for this is the fact that the more slender is the cranium, the more access the animal has to food, such as roots and tubers, growing in-between roots and holes. This factor could very well apply to *Oryctolagus cuniculus* inhabiting the Maltese rocky terrain.

While the particularity of the cranial shape is evident, the forces behind this adaptation are not and perhaps they will never be totally unravelled. However, it is evident that further research is required on this lagomorph, possibly research which targets the genetic aspect.

REFERENCES

Aspinall V. & O'Reilly M., 2007. Introduction to Veterinary Anatomy and Physiology. Butterworth-Heinemann, Oxford, 288 pp.

Baldacchino A.E. & Schembri P.J., 2002. Amfibji, Rettili, u Mammiferi fil-Gzejjer Maltin. Pieta: Publikazzjoni Indipendenza.

Barros F., Herrel A. & Kohlsdorf T., 2011. Head shape evolution in Gymnophthalmidae: does habitat use constrain the evolution of cranial design in fossorial lizards? Journal of Evolutionary Biology, 24: 2423–2433. https://doi. org/10.1111/j.1420-9101.2011.02372.x.

Endo H., Hayashi Y., Yamazaki K., Motokawa M., Pei J., Lin L., Chou C. & Oshida T., 2002. Geographical variation of the mandible size and shape in the wild pig (*Sus scrofa*) from Taiwan and Japan. Zoological Studies, 41: 452–460.

Fitter R.S.R., 1959. The Ark in Our Midst, the Story of the Introduced Animals of Britain: Birds, Beast, Reptiles, Amphibians, Fishes. London: Collins, 248 pp.

Foster J.B., 1964. The Evolution of Mammals on Islands. Nature, 202 (4929): 234–235.

Lin G., Ci H., Zhang T. & Su J., 2008. Conformity to Bergmann's rule in the plateau pika (*Ochotona curzoniae* Hodgson, 1857) on the Qinghai-Tibetan Plateau. Acta Zoologica Academiae Scientiarum Hungaricae, 54: 411–418.

Gans C., 1974. Biomechanics: an approach to vertebrate biology. University of Michigan Press, 272 pp.

Hopkins S.B. & Davis E.B., 2009. Quantitative morphological proxies for fossoriality in small mammals. Journal of Mammalogy, 90: 1449–1460 https://doi.org/10.1644/08-MAMM-A-262R1.1.

Jaksic F.M. & Scoriguer R.C., 1981. Predation Upon the European rabbit (*Oryctolagus cuniculus*) in Mediterranean Habitats of Chile and Spain: Comparative Analysis. Journal of Animal Ecology, 50: 269–281.

Meiri S. & Dayan T., 2003. On the Validity of Bergmann's Rule. Journal of Biogeography, 30: 331–351. https://doi.org/10.1046/j.1365-2699.2003.00837.x

Monnerot M., Vigne J.D., Biju-Duval C., Cassane D., Callou C., Hardy C., Mougel F., Soriguer R.C., Dennebouy N. & Mounolou J-C., 1994. Rabbit and Man: Genetic and Historic Approach. Genetics, Selection, Evolution, 26 (suppl.1): 167s–182s.

O'Malley B., 2007. Clinical Anatomy and Physiology of Exotic Species. Structure and function of mammals, birds, reptiles and amphibians. Elsevier Saunders, Edinburgh New York, 272 pp.

Sharples M., Fa J.E. & Bell D.J., 1996. Geographical variation in size in the European rabbit *Oryctolagus cuniculus* (Lagomorpha: Leporidae) in Western Europe and North Africa. Zoological Journal of the Linnean Society, 117: 141–158. https://doi.org/10.1111/j.1096-3642.1996.tb02153.x

Sherratt E., Gower D.J., Klingenberg C.P. & Wilkinson M., 2014. Evolution of cranial shape in caecilians (Amphibia: Gymnophiona). Evolutionary Biology, 41: 528–545. https://doi.org/10.1007/s11692-014-9287-2.

Szuma E., 2008. Geographic variation of tooth and skull sizes in the arctic fox *Vulpes* (*Alopex*) *lagopus*. Annales Zoologici Fennici, 45: 185–199. https://doi.org/ 10.5735/086.045.0304

Taylor J., Freedman L., Olivier 'I.J. & McCluskey J., 1977. Morphometric Distances between Australian Wild Rabbit Populations. Australian Journal of Zoology, 25: 721–732.

University of Arizona Cooperative Extension, 2000. Cleaning and Preserving Animal Skulls [pdf] Available at: <http://www http://ag.arizona.edu/pubs/natresources/az1144.pdf > [Accessed 27 June 2019].

van der Geer A., Lyras G., de Vos J. & Dermitzakis M., 2010. Evolution of Island Mammals: Adaptations and extinction of placental mammals on islands. Wiley-Blackwell, Hoboken, New Jersey, 496 pp.

van Heteren A.H., MacLarnon A., Soligo C. & Rae T.C., 2014. Functional morphology of the cave bear (*Ursus spelaeus*) cranium: a three-dimensional geometric morphometric analysis. Quaternary International, 339–340: 209–216. https://doi.org/ 10.1016/j.quaint.2013.10.056

van Heteren A.H., Maclarnon A., Soligo C. & Rae T.C., 2015. Functional morphology of the cave bear (*Ursus spelaeus*) mandible: a 3D geometric morphometric analysis. Organisms Diversity & Evolution, 16: 299–314. https://doi.org/10.1007/s13127-015-0238-2

Yahaya A., Olopade J.O., Kwari H.D. & Wiam I.M., 2012. Osteometry of the skull of one-humped camels. Part I: immature animals. Italian Journal of Anatomy and Embryology, 117: 23–33.