# Interpreting Palaeopathology: biographies of two draught oxen

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## Abstract

The use of animal power in early cultures revolutionised agriculture and the relationships people had with animals. Attempts to identify draught animals in the archaeological record are one of the most common areas of investigation in zooarchaeological studies relating to pathological or sub-pathological deformations to bones. While such changes do affect the bones of draught animals, there are many other potential causative factors, rendering interpretation ambiguous. A recent opportunity to record the skeletons of two draught oxen with known life histories has provided new data that can be compared with archaeological material. This paper describes the skeletal modifications observed using widely accepted methods and compares findings with the biography of the animals. The results show relationships between the type of harness, persistent use of the animal on one side of a team and scale of pathological changes throughout the skeleton. Findings have the potential to refine how we identify and interpret draught animals in the archaeological record as well as informing aspects of welfare today.

## Résumé

L'utilisation de la force animale dans les cultures anciennes a révolutionné l'agriculture et les relations entre les hommes et les animaux. Par la suite, les tentatives d'identification des animaux de trait dans les trouvailles archéologiques constituent l'un des domaines d'étude les plus courants dans les recherches zooarchéologiques portant sur les déformations osseuses. Si les changements pathologiques affectent effectivement les os des animaux de trait, il existe de nombreux autres facteurs potentiels, ce qui rend l'interprétation ambiguë. Une récente opportunité d'examiner les squelettes de deux bœufs de trait a fourni de nouvelles données qui peuvent être comparées avec le matériel archéologique. Cet article décrit les modifications squelettiques observées à l'aide de méthodes largement acceptées et compare les résultats avec la biographie connue des animaux. Les résultats montrent des relations entre le type de harnais, l'utilisation persistante de l'animal d'un seul côté de l'attelage et l'ampleur des changements pathologiques dans l'ensemble du squelette. Ce projet pourrait permettre d'affiner la manière dont nous identifions et interprétons les animaux de trait dans les trouvailles archéologiques, tout en fournissant des informations sur certains aspects du bien-être animal aujourd'hui.

## Kurzfassung

Der Einsatz von tierischer Zugkraft in frühen Kulturen revolutionierte die Landwirtschaft und die Beziehungen der Menschen zu Tieren. In der Folge ist die Identifizierung von Zugtieren in archäologischen Funden einer der häufigsten Untersuchungsbereiche in der Zooarchäologie, die sich mit Knochenverformungen befasst. Zwar beeinflussen pathologische Veränderungen die Knochen von Zugtieren, doch gibt es viele andere mögliche Ursachen, was die Interpretation erschwert. Eine kürzlich erfolgte Untersuchung der Skelette zweier Zugochsen lieferte neue Daten, die mit archäologischem Material verglichen werden können. Dieser Artikel beschreibt die anhand allgemein anerkannter Methoden beobachteten Skelettveränderungen und vergleicht die Ergebnisse mit der bekannten Biografie der Tiere. Die Ergebnisse zeigen Zusammenhänge zwischen der Art des Geschirrs, der dauerhaften Nutzung des Tieres auf einer Seite des Gespanns und dem Ausmaß der pathologischen Veränderungen im gesamten Skelett. Das Projekt hat das Potenzial, die Identifizierung und Interpretation von Zugtieren in archäologischen Funden zu verfeinern und gleichzeitig Aufschluss über Aspekte des heutigen Tierschutzes zu geben.

## Resumen

El uso de la fuerza de tracción animal en las primeras culturas revolucionó la agricultura y las relaciones entre el hombre y los animales. En consecuencia, la identificación de ganado de tiro en hallazgos arqueológicos es uno de los campos de investigación más comunes en la zooarqueología, que se ocupa de las deformaciones óseas. Aunque los cambios patológicos afectan a los huesos del ganado de tiro, existen muchas otras causas posibles, lo que dificulta la interpretación. Un estudio reciente de los esqueletos de dos bueyes de tiro ha proporcionado nuevos datos que pueden compararse con el material arqueológico. Este artículo describe los cambios esqueléticos observados mediante métodos generalmente aceptados y compara los resultados con la biografía conocida de los animales. Los resultados muestran la relación entre el tipo de arnés, el uso prolongado del animal en un lado del tiro y la dimensión de los cambios patológicos en todo el esqueleto. El proyecto tiene el potencial de perfeccionar la identificación e interpretación del ganado de tiro en los hallazgos arqueológicos, al mismo tiempo, proporcionar información sobre aspectos relacionados con el bienestar animal en la actualidad.


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## Methods

The skeletal remains of two draught oxen were examined macroscopically and recorded in detail with the aim of providing data to investigate the extent to which the working lives of the two oxen are reflected in skeletal changes, and to test commonly used zooarchaeological methods to analyse size, age and sex of cattle in the archaeological record. Recording focused on pathological and sub-pathological observations and measurements of the long bones and skull. In addition, basic data such as anatomy, side, tooth wear, fusion of the epiphyses and butchery were recorded. All elements were photographed and weighed. Data are available at https://doi.org/10.6084/m9.figshare.30665003.

### Recording pathological and sub-pathological changes

Traditional zooarchaeological methods employed to investigate the use of cattle for draught work has focused on the autopodia (metapodials and phalanges) and horns[1]. Bartosiewicz et al. provided methods to record changes affecting the autopodia by ascribing a score to the severity of changes on a scale of 1 (none) to 4 (severe). These scores can be converted into a *pathological index* to summarise the extent of the changes in an animal or population of animals within the archaeological record. Subsequent research has been carried out to refine these methods, taking into account the effect of fragmentation, body weight/ size and age on the pathological and sub-pathological changes observed. The resulting *modified pathological index* (mPI) devised by Holmes et al. was used to record deformations of the autopodia of the two cattle[2].

Deformations of other elements (skull, vertebrae, long bones and pelves) do not currently have a recognised recording protocol, but basic pathological indices were assigned to them to make the extent of changes comparable to those for autopodia. This presents a new method that is open to refinement. For definitions of terminology see *Histories written in (cattle) bone – an archaeozoological and osteological perspective* (this volume).

Crania: symmetry of the skull was investigated by taking measurements along the midline above the os nasale along the entire os frontale up to the frontal eminence to determine any axial deviations.

Vertebrae: a scale of severity was devised to record pathological and sub-pathological changes. The following deformations were recorded and are illustrated in ***Figure 1***: Pitting (scale of 0-3), grooving (scale of 0-2), enthesophytes (scale of 0-3), osteophytes (scale of 0-2) and eburnation (presence of absence) on the cranial and caudal articular surfaces; osteophytes and enthesophytes of the lateral processes; asymmetry (presence or absence) of the dorsal and ventral processes; enthesophytes affecting the dorsal process; and articular contour change. In all cases 0 represents no change, and the higher numerical value represents most severe change.

Long bones and pelves: The presence or absence of enthesophytes, osteophytes, eburnation, grooving and pitting was recorded for the proximal and distal articulations and shafts as well as any asymmetry, fused elements or other lesions.

Values were ascribed to the deformations of the vertebrae and long bones to allow them to be easily compared with the autopodia:

*Pathological value* = score/ total possible score*

*the total possible score includes only observable zones, for example, where metatarsals have fused tarsals at the proximal articulation the score did not include pitting, eburnation or grooving as it was impossible to record these changes.

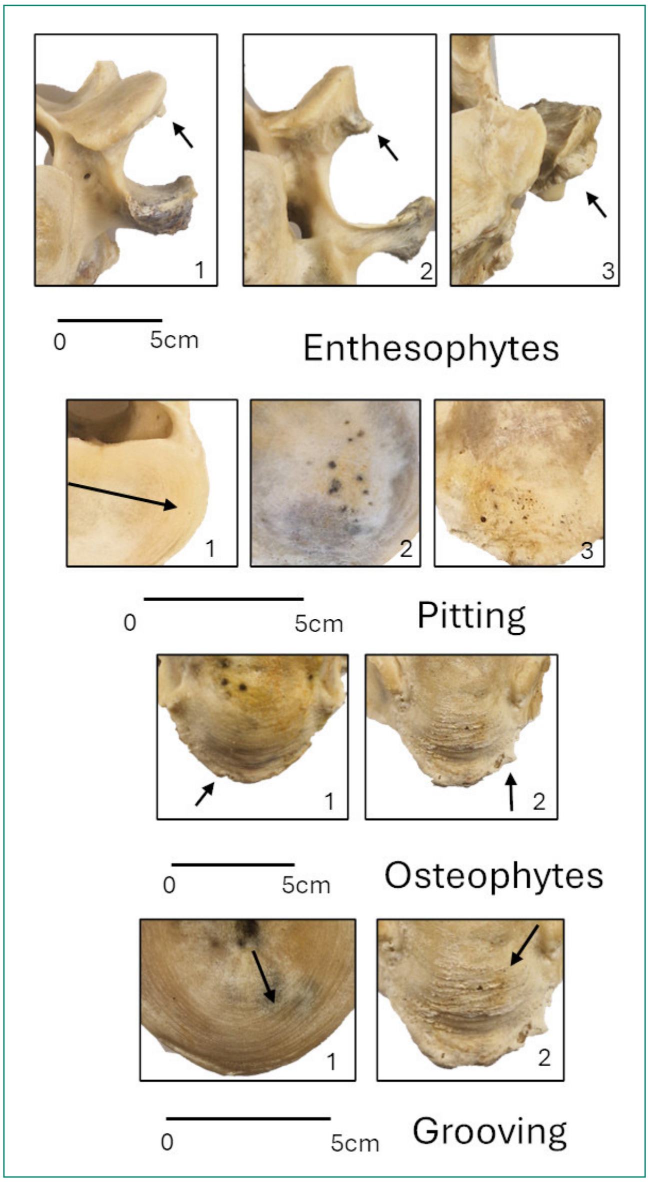


***Fig. 1*** *Scale of deformations recorded for vertebrae.*

### Measurements

Long bone measurements were recorded following von den Driesch[3]. Sex was investigated using pelvis morphology[4] and metacarpal measurements[5]. Heights were calculated using greatest length measurements of the long bones[6].

1 Holmes et al. 2021, Thomas et al. 2021, Bartosiewicz et al. 1997, Onar and Kahvecioğlu 2015.
2 Holmes et al. 2021.
3 Von den Driesch 1976.
4 Greenfield 2006.
5 Davis et al. 2012.
6 Matolcsi 1970.

## Biographies

*Mani* (***Figures 2 and 3***)

Mani was a draft ox of the Vosges breed, just under eleven years old at the time of slaughter, with a withers height of 145 cm and a live weight of 780 kg. He started work at two and was castrated at the age of three. On the farm in the French Vosges mountains, Mani was harnessed in a double head yoke as a team of two, mostly on the right side. The ox's workload was considerable: mainly used for logging, transporting hay and manure and haymaking, in particular turning and raking hay. During the summer there were peaks of up to 5 hours of work per day, 5 days a week. The nature of the landscape meant that Mani worked primarily on slopes, some very steep. During the growing season, the ox was usually kept outside, while in winter he was housed in a stone barn with a hard floor. Until the time of slaughter, he was still regularly used for work.

***Fig. 2*** *Mani logging in the Vosges mountains with his owner Philippe Kuhlmann and wearing a double head yoke (Photo: M. Nioulou).*

***Fig. 3*** *Mani (on the left) during a heavy pull in a double head yoke. Visible is the asymmetrical tension in the neck area due to different head positioning of the two animals (Photo: M. Nioulou).*

Videos of Mani moving at work and being led in hand were examined by B. Corson. There was no obvious lameness in any single limb, though several indications of altered musculoskeletal and/ or neurological dysfunction were observed:

- Asymmetrical oscillations of the body when walking, with the body curving more strongly to the right than the left;
- Asymmetrically shortened stride length in the hind limbs (failure to "track up"), the right subjectively more severe than the left;
- Occasional slight circumduction of the right hind limb;
- Inconsistent toe dragging in both hind limbs;
- Asymmetry of the pelvic landmarks, with the right ilium and ischium subjectively lower than the right;
- Occasional abrupt tail swishing, consistent with discomfort, pain or irritation.

*Darius* (***Figures 4 and 5***)

Darius was a draft ox of the Rhaetian Grey breed, slightly over twelve years old at the time of slaughter, with a wither height of 138 cm and a live weight of 700 kg. He started work at two and was castrated at the age of two and a half years. Darius was usually harnessed in a three-pad collar and used in a team and for individual tasks. His workload was not particularly hard in his early years; it was only from the age of six onwards that he was used for more demanding agricultural work such as ploughing. During particularly intensive work phases, Darius was used up to four times a week for 1-3 hours per day, almost exclusively on flat terrain. The ox was kept outdoors all year round, but had a straw-strewn shelter available during the winter months.

For the six months prior to slaughter, Darius was no longer used for heavy work, as he had developed signs of pain in the shoulder area while pulling heavy loads.

***Fig. 4*** *Draft ox Darius in 2017 during an agricultural field day harnessed with a three-pad collar (Photo: M. Funke).*

***Fig. 5*** *Darius during heavy plowing as a single in a three-pad collar (Photo: A. Keil).*

## Results – Mani

### Age, sex, height

The mandibular wear stage was calculated at J, consistent with an animal between 8 and 16 years of age. Although all long bones were fused, the second cervical to tenth thoracic vertebrae had incomplete fusion of the anterior and ventral physes (***Figure 6***). The pelvis was morphologically consistent with a male, and the metacarpal measurements plotted with males[7].

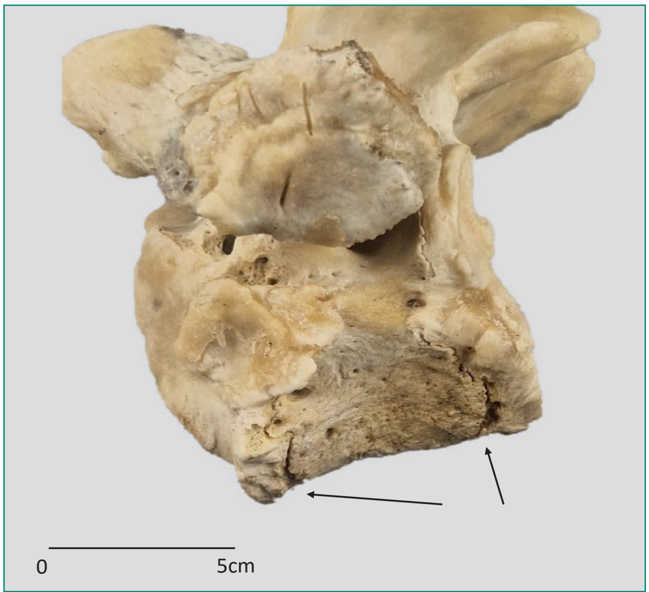


***Fig. 6*** *Fusion line of physis on a thoracic vertebra.*

Depending on the long bone used to calculate them, heights ranged from 153cm to 175cm (mean= 164cm; median= 161cm), and all measurements from the left side were slightly lower than the right side (***Table 1*** *in Suppl. Data Rep.*). A paired sample T-test was used to compare the lengths of the major long bones from both sides, which produced a significant difference (t= -3.97, p= 0.01), with those on the left (mean= 38.5; SD= 10.8) being shorter than those on the right (mean= 38.7; SD= 10.7).

### Axial skeleton

Skull – axial asymmetry was observed visually and confirmed by the metrical data: the frontal bone above the orbita was deformed a maximum of 12mm towards the left (***Figure 7***). There was bilateral malocclusion of the second premolars and first molars of the maxillae and mandibles.

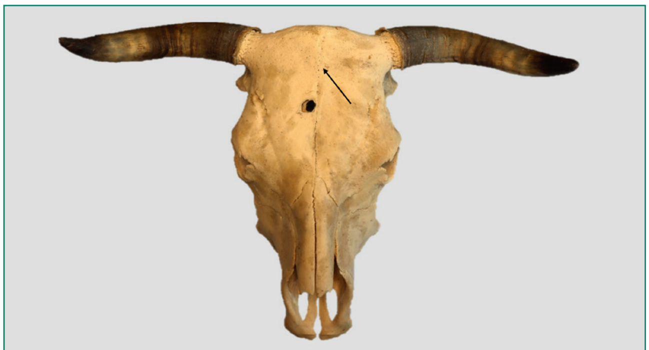

***Fig. 7*** *The skull of Mani illustrating the asymmetry in the longitudinal plane.*

7 Davis et al. 2012.

Vertebrae - considerable deformations affected all, but particularly the second cervical to the seventh thoracic vertebra (***Figures 8*** and ***9***). All ribs exhibited eburnation and articular contour change.

Pelvis– the pelvis was fused at the pubic symphysis and as well as exhibiting prolific enthesophytes and osteophytes, the acetabular rim had slight articular contour change and eburnation.

### Upper limb bones

Enthesophytes were present and common on all upper limb bones, to the point that recording each individually was hindered by the time available. Instead, each bone was photographed to illustrate the nature of the enthesophytes (available in the supplementary data). ***Table 2*** (in Suppl. Data Rep.) and ***Figures 8*** and ***9*** summarise the pathological changes affecting the major limb bones.

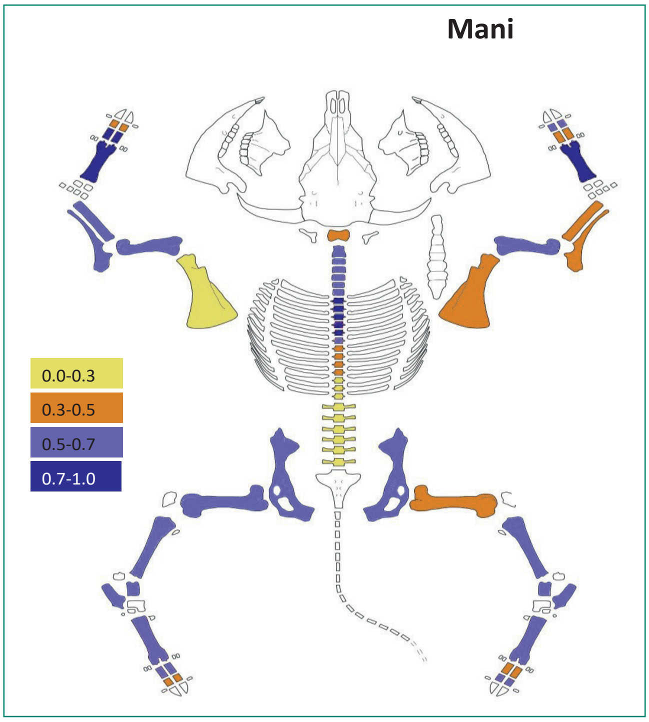


***Fig. 8*** *Relative severity of deformations affecting the skeleton of Mani.*

Scores ranged from 0.20 (right scapula) to 0.63 (tibiae) and were generally similar for the left and right sides, except for the right radius and ulna and right femur, which were less affected than those of the left. Of note were the scapulae, both of which had relatively low scores when compared to other elements; fusion of the left os malleolare to the left distal tibia; and both astragali that had considerable deformations due to the broadening of the distal end (***Figure 10***). Carpals were also commonly affected; and the left radial and lunate were fused together.

### Autopodia

The autopodia pathology scores are slightly greater for the foreleg (anterior), ranging from 0.45 to 0.88, than the hindleg (posterior), ranging from 0.38 to 0.64. This is to be expected as the forelimbs carry most weight in cattle and so are affected by pathological and sub-pathological changes more than those of the hindlimbs[8].

8 Bartosiewicz et al. 1997, Holmes et al. 2021, Thomas et al. 2021.

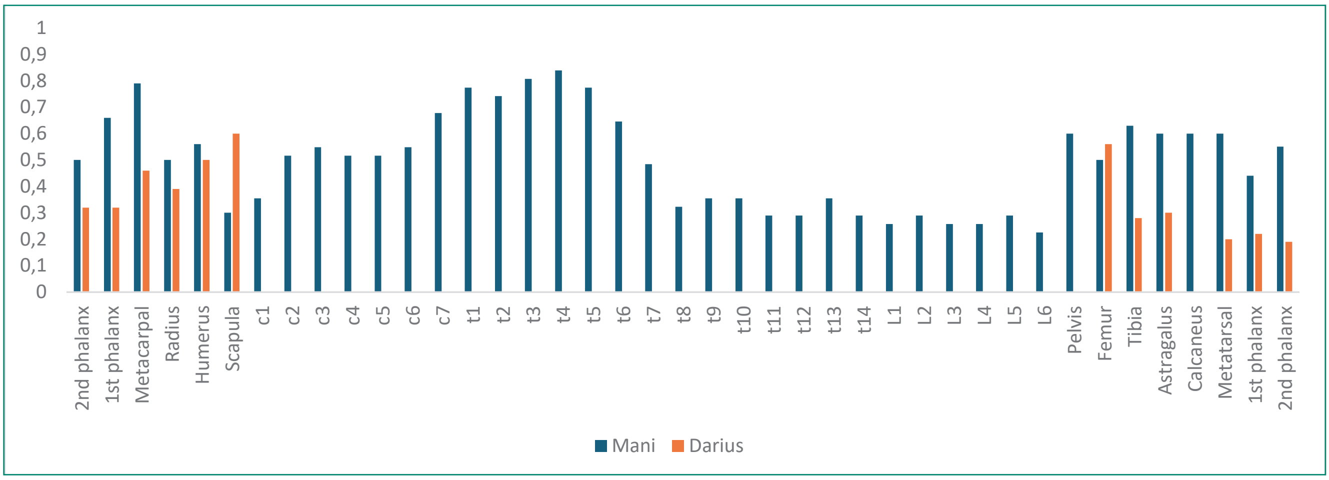


***Fig. 9*** *Relative severity of deformations affecting the major limb bones, combined scores*

All pairs of sesamoids were fused together, except for one pair from the right foreleg. All had articular contour change and one of those from the left hind limb had grooving.

There was no significant difference between the left and right scores of the upper limb bones or autopodia when tested with a paired T-test.

## Results – Darius

### Age, sex, height

As with Mani, the mandibular wear stage indicates that Darius was between 8 and 16 years of age. All long bones were fused. Although the pelvis was not present, the metacarpal measurements were consistent with a male. The mandible exhibited bilateral malocclusion of the lower second premolar.


***Fig. 10*** *Illustration of deformation affecting the right astragalus of Mani, observed as broadening of the distal trochlea.*

Heights varied from 147cm to 162cm (mean= 154cm; median= 154cm) (***Table 1*** in Suppl. Data Rep.) and there was no statistical difference between the left and right sides when compared with a paired T-test (t= 1.62, p= 0.16).

### Axial skeleton

The skull, vertebrae and pelves were not available.

### Upper limbs

Scores ranged from 0.0 (right astragalus and both calcanea) to 0.7 (left femur) (***Table 2*** in Suppl. Data Rep., ***Figures 9*** and ***11***), with both scapulae also scoring high (0.6). Although there was no significant difference between the pathological scores of the left or right sides, the right humerus and astragalus and left femur were more affected than their associated element.

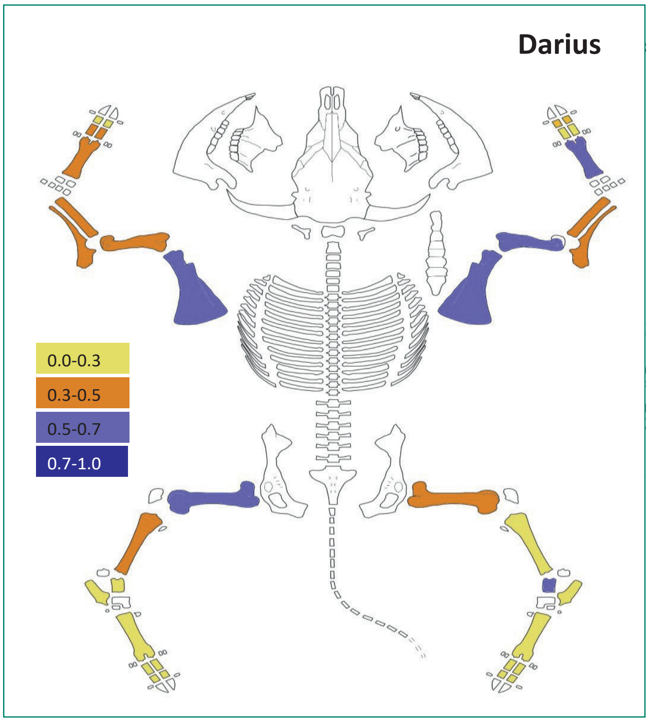


***Fig. 11*** *Relative severity of deformations affecting the skeleton of Darius.*

### Autopodia

Pathological indices for the autopodia ranged from 0.25 to 0.50 for the forelegs and 0.14 to 0.25 for the hindlegs (*Table 2* in Suppl. Data Rep., *Figures 9* and *11*).

There was no significant difference between the left and right scores of the upper limb bones or autopodia when tested with a paired T-test.

## Discussion

Skeletal analysis of the two draught cattle allowed the testing of commonly used zooarchaeological sexing and ageing methods, which provided consistent data reflecting the known life histories of the two oxen. However, the heights calculated from the lengths of bones using widely accepted indices were greater than the live values for both animals, the means varying by c.19cm for Mani and c.16cm for Darius. The range of heights calculated using different bones also varied considerably: a discrepancy of nearly 20cm for Mani and 15cm for Darius. Taken together, this suggests that the use of absolute heights with archaeological data should be treated with caution.

The incomplete fusion of Mani's cervical and thoracic vertebrae was unexpected. These bones are expected to close in the fifth year[9], although a study of 112 modern bulls of 6 breeds, ranging from 1 to over 15 years found that in 5-year-old bulls at least half the vertebral epiphyses were fused, while only 10% of the thoracic vertebrae remained open at 6-years of age[10]. It may therefore be expected, under normal circumstances and taking into account delayed fusion caused by castration, that fusion would be complete in an animal as old as Mani. Given that Mani began work at 2 years, before the cervical and thoracic vertebra had completely fused, it is possible that the subsequent strain from his workload prevented them from doing so.

Overall, the combined, comparable, limb and autopodia scores for Mani (mean= 0.54, SD=0.16) were significantly greater (t= 4.2, p= <.005) than Darius (mean= 0.33, SD= 0.19). Although they used an unmodified pathological index, the autopodia pathological index values for working oxen (between 0.17 and 0.40) recorded by Bartosiewicz[11] were comparable to those of Darius (0.28) both being considerably lower than the scores for Mani (0.59).

This implies that Mani was severely affected by his working life to a greater extent than Darius. While it is possible that Mani could have had a systemic pre-disposition to bone deformations, the combination of enthesophytes recorded on all long bones indicating strain placed on the soft tissues and differences between the severity of pathological indices between the left and right sides (radius/ ulna and femur), indicates that the cause was more likely to be external. Furthermore, these findings are consistent with the observable asymmetry in Mani's gait described above.

One likely factor causing such a difference in the pathological scores of the two oxen is the different workloads they were subjected to. For example, where Mani had to work up to 5 hours, walking over 20 km a day during the hay season, Darius would have worked for only a few hours maximum. The landscape would also have had an effect as Mani worked on steep hillsides, while Darius only ever had to work on flat land.

As well as having distinct workloads, the two oxen were harnessed differently, and it is likely that some of the pathological and sub-pathological changes reflect this. The double head yoke (used by Mani), especially when employed on steep terrain, has specific characteristics:

- Individual animals do not pull in a straight line, but tend to push either toward the centre of the yoke (where the chain is attached) or outward. This leads to asymmetrical strain on the head, front limbs and spine.
- Since the yoke is attached behind the horns in the neck area (with the pull being taken up by the forehead plate), use on steep terrain or with animals of different sizes also leads to increased, sometimes asymmetrical tension and pressure points from the yoke bow in the animals' neck area.
- With a head harness, the pulling force is taken from the forehead area and, accordingly, changes in the pulling angle are compensated for by a change in head posture. This, in turn, has an impact on the skull and spine.

All three of these aspects of the double head yoke may explain the high pathological scores of Mani's second cervical to seventh thoracic vertebrae, and the asymmetrical morphology of those vertebrae and the skull itself. The position of Mani on the right side of the pair is also consistent with the shorter limb bones, greater deformation scores and pathological scores of some left elements that combine to suggest he placed more weight on the inside during his working life.

The skull is complex in its development, functions and adult morphology. It is difficult to measure with consistency, but Mani's skull was markedly asymmetrical. The causality of asymmetry can be difficult to assess, as it could potentially be affected by adaptive and functional vs mal-adaptive/ pathological factors[12]. However, it remains possible that it was caused or exacerbated by his pushing into the left side of the head yoke.

The use of an adjustable three-pad collar, such as that used by Darius, also has specific effects on the animal:

- 90% of the pull is taken up by the shoulders and only 10% by the neck.
- If the collar padding is misaligned due to a pull angle that is too flat or too steep, there can be uneven strain on the shoulder joint. Unlike the head yoke, animals cannot correct the pull angle themselves.

Although no vertebrae were available for Darius, his scapulae and right humerus had high scores, the former were affected to a greater extent than those recorded for Mani (*Table 2* in Suppl. Data Rep.). It is highly likely that this reflects the use of the three-pad collar, which would have transferred the load into Darius shoulders. There is no one-sided tension produced by a three-pad collar and this can be observed in the similar bone measurements and pathology scores from left and right sides.

## Conclusion

Bone disorders are multifactorial and complex, so caution must be taken when drawing conclusions relating to the

9 Silver 1969.

10 Thomson 1969.

11 Bartosiewicz et al. 1997. Table 18

12 For example, Ono et al 2023 and Frost 2003.

cause and effect of pathological and sub-pathological changes in isolation. However, this study has served to illustrate that inferences can be made, even if tentatively, when such deformations are integrated with known life histories. Further work needs to be carried out on similar animals to place the results of this investigation in context, but as a preliminary study it has provided a base line data set for future studies that might incorporate upper limb bones and the axial skeleton.

From an animal health perspective, additional methods for investigating changes in the skull and other skeletal tissues could include serum chemistry and hormone levels in the living animal and histology, radiology, or mineral analysis in postmortem samples. Many studies have examined the effect of occupations on the human skeleton[13] and animals[14] but studies of the effects of work on draught cattle tissues are less common. This study has shown how severe such changes can be, and this and future investigations will be crucial to inform better health and welfare in working animals. The combination of a greater workload, harness and extreme terrain have affected the skeleton of Mani to a much greater degree than Darius, and factors such as these should be taken into account when working with animals and some allowance given to duration and nature of the work and harnessing choices if possible. The importance of using a well-matched pair of cattle in a head yoke has been reinforced by the asymmetry affecting Mani. The pressure of the three-pad harness is also not without adverse effects, possibly causing lameness observable as deformations to the shoulders (scapulae and right humerus) in Darius.

In zooarchaeology, consideration of the skeletal changes to draught cattle have focused largely on the autopodia and, less commonly, the horns, skull and pelvis. This study has shown that the upper limbs and vertebrae can be affected as much as the lower limbs and that there is potential for detailed biographies to be attempted from complete skeletons in the archaeological record, illustrating the potential for different harnessing methods to affect the skeleton, in particular the axial skeleton, scapulae and femora. This method is in its infancy, and is not without challenge, but it is hoped that it will provide a stepping stone for more detailed consideration of the pathological and sub-pathological deformations affecting the whole body of working animals.

Note: From experience, M Holmes notes that the pathological and sub-pathological changes recorded on Mani's bones are greater than any she has observed on cattle in the archaeological record. This suggests he was potentially subjected to more intense work, over a longer period than many of those draught animals in our past. Comparisons are easier to make with horse remains, which commonly exhibit enthesophytes, exostoses, articular contour change and osteophytes similar to those recorded on Mani. However, Mani represents one animal, who may have been susceptible to bone deformations and further work needs to be carried out on other working animals with known biographies.

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13 For example Barbe and Popoff 2020, Gemne and Saraste 1987, Alves-Cardoso and Assis 2021.

14 For example Salmi et al. 2020, Broster et al. 2009, Diedrich 2017.

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