Some remarkable bone disorders in digits of a roe deer (*Capreolus capreolus*)

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Abstract: A mummified roe deer (*Capreolus capreolus*), found in a casemate in the dunes near Haamstede, province of Zeeland, the Netherlands, showed at the distal interphalangial joints of the right front and the right hind feet a combination of severe destruction and proliferative osteal reactions of the bordering phalanxes. The specific location reminds of foot-rot, a well known condition in sheep and goats. Comparison with unaffected roe deer feet, at the front as well as the hind feet, show a shortening of the length and an increased breadth of phalanx 2, while the standard measurements of phalanx 3 hardly show any changes in measurements. It is quite likely that the condition has been acquired by trotting near water holes in mud and faeces, resulting in contamination with micro-organisms that cause footrot. As a consequence, the space between both hoofed digits were infected and led ultimately to a suppurative arthritis. The location of the inflammatory reactions - the phalanxes - and the pathological anatomic characteristics, lead to foot rot as being the most probable explanation for this condition. However, other microbiological causes, cannot be excluded.

Keywords: *Capreolus capreolus*, roe deer, distal interphalangeal joint, arthritic infection.

Introduction

Although in adult roe deer (*Capreolus capreolus*) hunting and traffic are amongst the most frequent causes of death in western Europe (e.g. in Baden-Württemberg > 90%, Linderoth 2005), this species is also known to suffer from certain diseases like verminous pneumonia caused by lungworms (*Dictyocaulus* spp.) (Chapman 1977) or *Vareostrongylus capreoli* (Schwarz et al. 2011), tuberculosis (Pavlik et al. 2005, Weikel et al. 2010) or actinomycosis (Konjević et al. 2011).

The effects of bone diseases in humans and also in domestic animals are documented during life, incidentally post-mortem, and are described with an array of picture imaging technics, as e.g. X-ray radiography, computed tomography (CT) or magnetic resonance imaging (MRI). In wild animals, however, reports of bone lesions are incidental and systematic surveys of specific diseases as described in van Soest et al. (1972) and Konjević et al. (2011) are even more scarcely presented.

A field vole (*Microtus agrestis*), found in pellets of a long-eared owl (*Asio otus*), showing a thickened lower jaw (and a fracture of the lower left incisor), was diagnosed as actinomycosis (Bauchau & Le Boulange-Nguyen 1985). Even in fossil bones sometimes acquired bone lesions are preserved, as in the case Bil (1994) presented of a thickened rib of a woolly mammoth (*Mammuthus primigenius*), showing on a X-ray photo a callus formation with signs of infection and a sequester. In 2007 Konjević et al. (2011) studied more than 27,000 mandibles of adult roe deer and found chronic pyogranulomatous osteomyelitis ("lumpy jaw") in 113 mandibles (7.0%), ascribed to actinomycosis. Handeland et al. (2010) described outbreaks of digital necrobacillosis in Norwegian wild

tundra reindeer (*Rangifer tarandus tarandus*). Single feet from 20 animals and six whole carcasses, collected in 2007 and 2008, were submitted for laboratory examination: *Fusobacterium necrophorum* was cultured from the foot lesions of six (23%) animals. Van Soest et al. (1972) reported an even higher incidence of bone lesions caused by the nematode *Skrjabingylus nasicola* around the frontal sinuses of stoats (*Mustela erminea*) and weasels (*Mustela nivalis*), being respectively 56% and 41%. Similar lesions were described in polecats (*Mustela putorius*) too (Kierdorf et al. 2006).

In this paper the discovery of a mummified roe deer reveals unexpected arthritic lesions of the 2nd and 3rd phalanxes of right fore and hind foot. A description and measurements of the pathological deformed bone fragments is documented.

Material and methods

During the 2006 annual winter census of hibernating bats in Haamstede (province of Zeeland, the Netherlands) a mummified female roe deer had been noticed in a casemate on Theunesses Hill in the Westerenban van Schouwen, province of Zeeland (51°42'00"N, 003°42'08"E) and then let untouched. The specimen, with its head still included at the time, was observed hanging with the right side against the wall on a nail above the dry sandy ground. During the annual bat counting in February 2017, the remaining hide and attached bones were recovered; the skull, mandibles and first cervical vertebra and left fore and hind leg were missing. Several small extremity bones were found under the mummified carcass and collected. In the open entrance to another part of the casemate, a skull of a female roe deer was present and also collected.

In January 2018 in the room of the casemate, in which the specimen was found, the sand was searched for the small bone elements using a sieve with a diameter of 3 mm. Besides several bony fragments of rabbits (*Oryctolagus cuniculus*) of at least six specimens, a triple twisted copper thread of almost three and a half metres, and fragments of ignited fireworks, no other bone elements of roe deer could be found. The mentioned open entrance of the casemate was searched by reefing the sand surface to an approximate depth of 10 cm, and also in this part of the casemate no more bone parts of roe deer were found.

Early 2017 the full grown buckthorn (*Hippophae rhamnoides*) and bramble (*Rubus* sp.) bushes around the casemate were cut and cleared to restore a situation of open areas in these dunes - so a chance to retrieve other remains of the roe deer seemed to be nil.

Nomenclature, including the used abbreviations, and all measurements taken of the phalanxes 2 and 3 are according to von den Driesch (1976). Remains, i.c. the phalanxes 2 and 3, of a female roe deer, found dead in a residential area of Oostkapelle (Walcheren, province of Zeeland) were used for comparison. For a proper orientation the different views are visualised in a picture of a fore foot (figure 1). Of phalanx 2 the greatest length (GL), the greatest breadth of the proximal end (Bp), the smallest breadth of the diaphysis (SD) and the greatest breadth of the distal end were measured (figure 1). Of phalanx 3 the diagonal length of the sole (DLS), the length of the dorsal surface (Ld) and the middle breadth of the sole (MBS) were measured (figure 1). Photographs are presented of the phalanxes with affected articulating facets; photographs of an unaffected roe deer are presented as comparison.

Permission to enter the casemate to perform prohibited acts in the context of counting of hibernating bats, as mentioned in the Flora- en Faunawet, was granted (Nr. 2016/62). Retrieval of the mummified remains of the roe deer was done with the permission of two employees of the State Forestry (SBB Westenschouwen). The collected remains were added to the collection (NHG26997) of the *Koninklijk Zeeuwsch Genootschap der Wetenschappen* (KZGW, Royal Zeeland Scientific

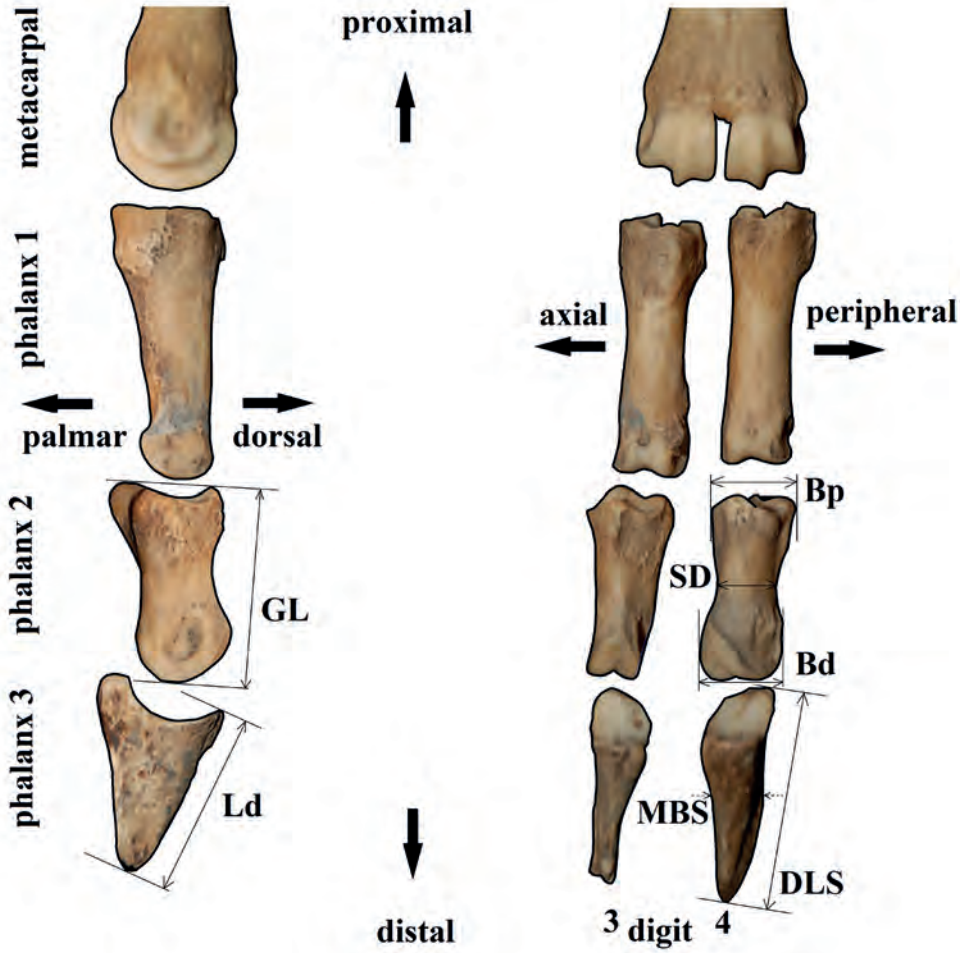

Figure 1. Right fore foot of a deer in peripheral and dorsal views with the metacarpal bones and the phalanxes 1, 2 and 3 of digits 3 and 4. The used views are indicated. Explanation of the used measurements of phalanx 2: greatest length (GL), greatest breadth of the proximal end (Bp), smallest breadth of the diaphysis (SD) and greatest breadth of the distal end (Bd), resp. of phalanx 3: diagonal length of the sole (DLS), length of the dorsal surface (Ld) and middle breadth of the sole (MBS). For the hind foot the method to take the measurements is the same as in the fore foot.

Society), located in the Zeeuws Museum in Middelburg, in the province of Zeeland.

Results

The dissection of the remains revealed several interesting details. The mummified skin covered most of the right side of the body. At the front right side of the thorax an almost circular shaped hole (ca. 5 x 4 cm.) was present, partly covering the broken third, fourth and fifth rib. The proximal part of the third rib was intact, while most of the corpus was missing. The fourth and fifth ribs were fractured, just above the corpus of these ribs. The dimension of the hole in the skin and the location and nature of the fractured ribs, all match with a gunshot. Under the left costal vertebrae transversal remnants of cardboard were in situ, seemingly residue of fireworks.

The collected bones recovered from the case-

Table 1. Standard measurements (in mm) of phalanx 2 (2) and phalanx 3 (3) of resp. fore and hind right digit IV for a roe deer recovered from a casemate compared with a female specimen from Oostkapelle, Walcheren; GL: greatest length, Bp: breadth of the proximal end, SD: smallest breadth of the diaphysis, Bd: breadth of the distal end, DLS: diagonal length of the sole, Ld: length of the dorsal surface, MBS: middle breadth of the sole. All measurements according to von den Driesch (1976).

	GL(2)	Bp(2)	SD(2)	Bd(2)	DLS(3)	Ld(3)	MBS(3)
NHG2699 (fore)	21.50	13.55	12.30	14.05	23.40	21.05	6.40
♀ *C. capreolus* (fore)	22.00	9.55	7.05	7.70	22.55	20.30	5.30
NHG2699 (hind)	22.55	11.10	10.50	16.60	24.35	24.75	6.15
♀ *C. capreolus* (hind)	26.40	10.20	7.20	7.70	25.40	25.10	6.30

mate all show completely fused epiphyses of the long bones, the vertebrae and other single bones, indicating an adult roe deer. The skull, without pedicles of antler outgrow, collected from the entrance of the casemate indicate a female adult roe deer. The second premolar as well as the third molars in the skull were well worn, indicating an age of at least eight years.

Phalanx 2 of the fourth right fore digit shows irregular deformations of the diaphysis and the distal epiphysis, resulting in complete disappearance of the distal articulating facet. The adjacent phalanx 3 also revealed deformations of the articulating facet and the adjoining part of half of this bone element (figure 2). Of the distal interphalangeal joint both articular facets are completely absent leaving at the proximal side a small cavity, a proliferation and an irregular surface with two small newly formed articulating facets. At the distal side a cavity, aligned at both sides by two small, newly formed articulating facets, is formed.

The phalanxes 2 and 3 of the fourth right hind digit (figure 3) show basically the same deformations of these of the fourth right fore digit distal joint as is shown in figure 2, however there are some differences. The general outline of phalanx 2 can best be described as an inverted "Y", with an intact proximal articulating facet. The original diaphysis seems to be bifurcated towards the distal end, leaving the original epiphysis, the axial arm of the "Y", shortened with complete loss of the distal articulating facet and a new articulating ridge at the axial side and a round articulating knob at the peripheral side. At the distal side of the peripheral arm of the "Y", a trochlea has been shaped, fitting the remnants of the excavated articulating facet of phalanx 3.

The greatest length (GL) of phalanx 2 of the fore right digit IV for the casemate roe deer is slightly shorter than that of the comparing specimen, for the hind right digit IV this length is markedly shorter (table 1). The breadth of the proximal end (Bp) is markedly broader in the fore digit and slightly broader in the hind digit. The smallest breadth of the diaphysis (SD) is extremely broader in the fore digit and markedly broader in that of the hind digit. The breadths of the distal end (Bd) in fore and hind phalanxes 2 are almost doubled or more (table 1).

All standard measurements of phalanx 3 of the fore and hind right digit IV of the casemate roe deer are close to the measurements of the comparing specimen, except for the breadths in the middle of the sole of the fore side, which is slightly wider. The total length of the phalanxes 2 and 3 of the fore right digit, in functional position, compared with the unaffected female roe deer show a length reduction of ca. 21%. If the two affected phalanxes in this digit are placed together in the functional position of the joint the axis of the articulation is in a slight plantar flexion (ca. 20 degrees) and deviated axially over ca. 40 degrees.

The total length of the phalanxes 2 and 3 of the hind right digit IV, in functional position and in peripheral dislocated position show length reductions of respectively 20% and

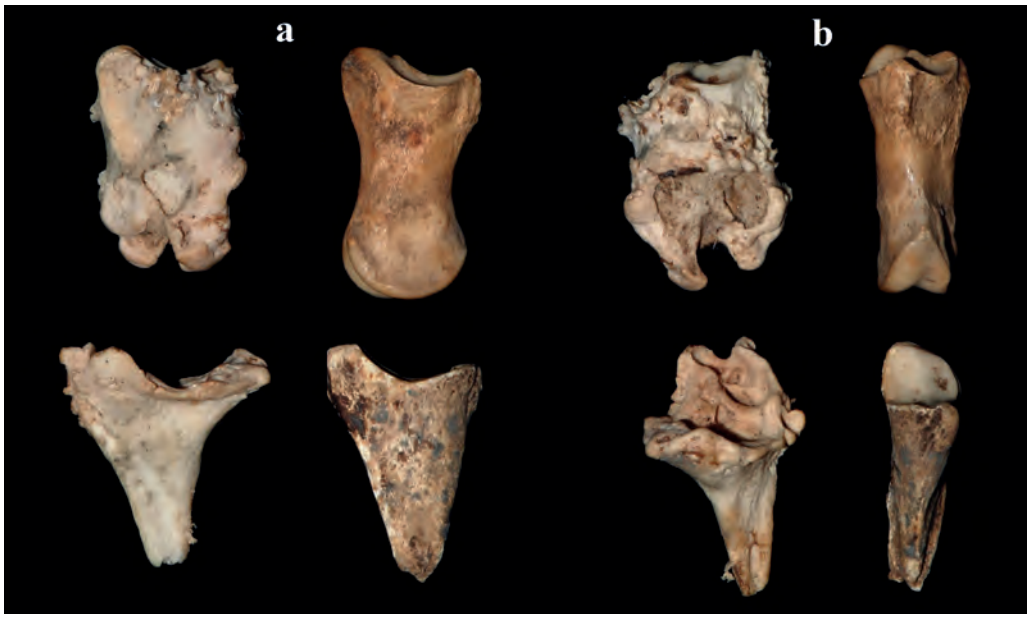

Figure 2. Phalanx 2 (top) and 3 (bottom) of the fourth right fore digit of the recovered roe deer (*Capreolus capreolus*) (left) in peripheral (a) and dorsal (b) views; for comparison an unaffected specimen (right).

23% compared with the unaffected female roe deer. If the two affected phalanxes of the hind right digit IV digit are placed together in the functional position of the joint, in the axial "Y" position, the axis of the articulation is in a slight plantar flexion (ca. 15 degrees) and deviated axially (ca. 30 degrees).

Discussion

Presumably the skull that was found in the open casemate entrance belonged to the mummified corpse, however, theoretically a small chance remains that two roe deer were involved. Taking that slight possibility for granted, the age category of the mummified roe deer could be estimated to be at least eight years.

The complete disappearance of both facets of the distal interphalangeal joint and the proliferation of the diaphysis of the forth middle phalanx digit at the right fore- and hind-side clearly points to an arthritis of microbial origin. The multiple cavitations and proliferation at the lateral side of the middle phalanxes match with a suppurative infection, of at least several months. At the other (available) bones no signs of destructive or constructive bone activity are present.

The origin of suppurative infections is unlikely to be of a systemic disease as tuberculosis, but rather caused by common infecting organisms. These infections may spread from inside the body, or may be introduced from outside by a perforating wound into the joint (Boyd 1961). A localised infection as foot-rot, well known to sheep farmers, is a specific disease in sheep (*Ovis aries*) affecting the interdigital skin and connective tissues, the joint capsule and the phalanxes 2 and 3. In a situation of animals trotting in muddy places with dung of other ruminants, especially when conditions are humid, micro-organisms can enter the weakened skin, and even infect deer (Egerton 2007). Transport through the skin can be accelerated through minor pricks of e.g. broken marram grass (*Ammophila arenaria*), bramble or buckthorns and even barbed wire. Amongst the causative pathogens *Fusobacterium necrophorum* (voided in

Figure 3. Phalanx 2 (top) and 3 (bottom) of the fourth right hind digit of the recovered roe deer (*Capreolus capreolus*) (left) in peripheral (a) and dorsal (b) views; for comparison an unaffected specimen (right).

the faeces) and *Dichelobacter nodosus* (a strict parasite of the epidermal tissues of the hooves of ruminants) are most likely to be present in sheep with foot-rot. These bacteria work synergistically in causing contagious foot-rot in sheep and goats (Underwood et al. 2015). In such infected areas tissue necrosis develops, surrounded by bacterial colonies of *Fusobacterium necrophorum*, ending up with characteristic foul-smelling waste gases produced by these bacteria (Cebra & Cebra 2012). Also other micro-organisms as *Streptococcus pyogenes* can be involved (Egerton 2007).

The micro-organisms belonging to *Actinomyces*, including those of the genus *Trueperella*, can cause actinomycosis in roe deer (Pewsner et al. 2017). Comparing the here described roe deer phalanxes with the bony lesions Konjević et al. (2011) described in the mandibles of roe deer with actinomycotic lesions, the causative agent *Actinomyces* cannot be excluded.

As the two joints both show destruction of the articulating facets, both with shortening of the middle phalanxes, the case of this roe deer can be described as suppurative arthritis. The fore-side lesion of the distal interphalangeal joint indicates a gradually slipping of the end phalanx 3 into the final position, during the loss of bone cortex, at the end with the mentioned length reduction of 21%. However, at the hind foot the "Y" shaped phalanx 2 indicates a dislocation from the original position of phalanx 3 towards the more peripheral position of this joint and a subsequent length reduction of 20% and 23%, respectively. In both phalanxes 2 of the fore and hind foot of the recovered roe deer, a marked, up until more than doubling of the breadth dimensions can be observed, while this is hardly the case in both phalanxes 3 (see figures 2, 3 and table 1). A reason for this difference could well be the effect of the tight structure of the hoofs: the triangular keratin sheath, covering the phalanx 3 from tip to bottom, constantly expresses a pressure, thus preventing proliferation of new bone.

Boyd (1961) describes eroding of the articular cartilage, exposing of the underlying bone and dislocation of the joint, disorders

described in roe deer NHG 26997, as the most severe form of suppurative arthritis. The crippling result of several months during infection almost certainly caused pain, lameness and a restricted range for the animal to feed. The fact that the animal was shot, therefore, can be considered as an act of mercy. Liggett (2004) speculates how a moose (*Alces alces*), affected with four types of osteoarthropathic lesions, apparently could have lived for a considerable time and concludes that diseased and weakened animals must have lived unmolested for quite a while in a 'modern' ecosystem, like we nowadays use to have almost everywhere in western-Europe, with its lack of large carnivores (due to their extirpation). In foot-rot the interdigital skin and hooves will be moist with a very distinctive necrotic odour (Underwood et al. 2015). This scent easily can be picked up by large carnivores. So, in an 'old-fashioned' ecological setting with a population of large carnivores, individuals of all species of hoofed animals with early stages of foot-rot and beginning lameness, would have been preyed upon before the disease process had time to change the bony structure so dramatically.

The casemate from where the roe deer was recovered most probably had been used by a poacher as a temporarily shelter: the secretly hiding of the shot roe deer and the found of twisted copper thread, undoubtedly to use for snares, clearly indicate this. The presence of fragments of ignited fireworks, found at the spine of the roe deer and on the floor, also show an alternative use of this casemate.

Conclusion

A roe deer showed post mortem characteristics of a suppurative arthritis of the right distal interphalangeal joints of the fourth digits of fore and hind foot. This process resulted in the fore foot in complete disappearance of the original distal interphalangeal joint and formation of new articulating structures and a length reduction of the combined phalanxes 2 and 3 of ca. 21%. The end stage in the hind foot also resulted in complete disappearance of the original distal interphalangeal joint and a length-reduction of the both phalanxes of ca. 20%. However, after a dislocation of this joint, again new articulating structures were formed ending up in a length reduction of 23%. Given the location of the affected phalanxes with bony lesions and comparing the pathological anatomical description, the diagnosis is most probably foot-rot, although other causing mechanisms cannot be excluded.

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References

Bauchau, V. & P. Le Boulange-Nguyen 1985. Une curieuze anomalie du crane chez *Microtus agrestis* (L., 1766). Lutra 28 (1): 22-25.

Bil, A. 1994. Een bijzondere afwijking bij een bijzonder dier: een pathologische afwijking aan een rib van de wolharige mammoet uit de collectie van het Zeeuw Genootschap. Zeeland 3 (1): 31-35.

Boyd, W. 1961. A textbook of pathology; structure and function in diseases. 7th edition. Lea & Febiger, Philadelphia, USA.

Cebra, C. & M. Cebra 2012. Diseases of the hematologic, immunologic, and lymphatic systems (multisystem diseases). In: D.G. Pugh & A.N. Baird (eds). Sheep and goat medicine. 2nd edition: 466-502. Elsevier, Amsterdam, the Netherlands.

Chapman, D.I. 1977. Genus *Capreolus*. In: G.B. Corbet & H.N. Southern (eds). The handbook of British mammals. 2nd edition: 437-446. Blackwell,

Oxford, UK.
Egerton, J.R. 2007. Diseases of the feet. In: I.D. Aitken (ed.). Diseases of sheep: 273-281. Blackwell, Oxford, UK.
Handeland, K., M. Boye, B. Bergsjø, H. Bondal, K. Isaksen & J.S. Agerholm 2010. Digital necrobacillosis in Norwegian wild tundra reindeer (*Rangifer tarandus tarandus*). Journal of Comparative Pathology 143 (1): 29-38.
Kierdorf, U., H. Kierdorf, D. Konjević & P. Lazar 2006. Remarks on cranial lesions in the European polecat (*Mustela putorius*) caused by helminth parasites. Veterinarski arhiv (Suppl.) 76: 101-109.
Konjević, D., I. Jelenko, K. Severin, H. Poličnik, Z. Janicki, A. Slavica, V. Njemirovskij, D. Stanin & B. Pokorny 2011. Prevalence of mandibular osteomyelitis in roe deer (*Capreolus capreolus*) in Slovenia. Journal of Wildlife Diseases 47 (2): 393–400.
Liggett, G.A. 2004. Osteoarthropathy in a moose (*Alces alces*) from Utah. Transactions of the Kansas Academy of Science 107 (1/2): 25-31.
Linderoth, P. 2005. Reh *Capreolus capreolus* (Linnaeus, 1758). In: M. Braun & F. Dieterlen (Hrsg.) Die Säugetiere Baden-Württembergs. Band 2: 588-604. Eugen Ulmer GmbH & Co, Stuttgart, Germany.
Pavlik, I., I. Trcka, I. Parmova, J. Svobodova, I. Melicharek, G. Nagy, Z. Cvetnic, M. Ocepek, M. Pate, M. Lipiec 2005. Detection of bovine and human tuberculosis in cattle and other animals in six Central uropean countries during the years 2000–2004. Veterinarni Medicina 50 (7): 291–299.
Pewsner, P., F.C. Origgi, J. Frey & M.-P. Ryser-Degiorgis 2017. Assessing fifty years of general health surveillance of roe deer in Switzerland: a retrospective analysis of necropsy reports. PLoS ONE 12 (1): e0170338.; https://doi.org/10.1371/journal.pone.0170338.
Schwarz, L., M. Frena, M. Skalicky & H. Prosl 2011. Endoparasitenbefall von Rehen in einem Revier in Niederösterreich. Wiener Tierärztliche Monatsschrift – Veterinary medicine Austria 98: 285-291.
Underwood, W.J., R. Blauwiekel & A. Schoell 2015. Biology and diseases of ruminants (sheep, goats, and cattle). In: J.G. Fox, L.C. Anderson, G.M. Otto, K.R. Pritchett-Corning & M.T. Whary (eds). Laboratory Animal Medicine. 3rd edition: 623-694. Elsevier Inc., San Diego, USA.
van Soest, R.W.M., J. van der Land & P.J.H. van Bree 1972. *Skrjabingylus nasicola* (Nematoda) in skulls of *Mustela erminea* and *Mustela nivalis* (Mammalia) from the Netherlands. Beaufortia 20 (265): 85-97.
von den Driesch, A. 1976. A guide to the measurement of animal bones from archaeological sites. Peabody Museum of Archaeology and Ethnology, Harvard University. Cambridge, Massachusetts, USA.
Weikel, J., W. Glawischnig, E. Hofer & K. Schöpf 2010. Tuberculosis in a deer (*Capreolus capreolus*) detected in Tyrol (Austria). Wiener Tierärztliche Monatsschrift 97 (11/12): 287-289.

Samenvatting

Enkele opmerkelijke botwoekeringen in tenen van een ree (*Capreolus capreolus*)

Een gemummificeerde ree, gevonden in een bunker op Schouwen-Duiveland, vertoonde aan de laatste gewrichten van zowel de rechter voorste als de rechter achterste vierde teen een combinatie van vergaande destructie en proliferatieve botreacties van de aangrenzende kootbeenderen. De specifieke locatie doet denken aan voetrot, een bekende aandoening bij schapen en geiten. Vergelijking met niet aangedane reeënpoten laat zowel aan voor- als achterpoot een verkorting en een verbreding zien van phalanx 2, terwijl de standaardmaten van phalanx 3 nauwelijks verandering vertonen. Het is zeer wel mogelijk dat de infectie is opgelopen doordat voetrot veroorzakende bacteriën, voorkomend in modder en faeces bij drinkplekken, de ruimte tussen de hoeven hebben geïnfecteerd en uiteindelijk hebben geleid tot een etterende gewrichtsontsteking. Gezien de locatie van de ontstekingsreacties, i.c. de kootbeenderen, en de pathologisch anatomische kenmerken is de meest waarschijnlijke aandoening voetrot, hoewel andere oorzaken niet zijn uit te sluiten.

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