Skeleton of an otter (*Lutra lutra*) with some regular and remarkable alterations

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Abstract: On 24 April 2019 the remains of an otter (*Lutra lutra*) were found on the verge of a road on the island of Sula (Norway). About 95% of skeletal elements were collected. Inspection revealed several recently broken ribs and vertebrae, that may have led to the death of this individual. This paper describes the previously existing skeletal lesions, discusses the most probable cause of death, and attempts to estimate the age of the specimen. A comparison of skull measurements to those of otters from elsewhere in Europe (n=74) shows that this specimen is well within the 25th and 75th percentiles. Measurements of the baculum length / weight, shows that this otter was in the top 15% for European otters (n=65). Based on these comparisons, the specimen can be described as an adult male. Evidence of strong grinding of dentals and (pre)molars corroborates this estimation. The presence of a narrow strip of bone at the ventral part of the ischium increased the accuracy of the age estimation, which is set at four to five years. Besides a healed longitudinal fracture of the shaft of the left fibula, there were signs of severe arthrosis deformans on the femoral-tibia joints and erosion and enthesopathies were also noticed on the left tibia, all more extreme than on the right side. Three thoracal vertebrae showed erosion of the endplates and osteophytes to the stages of interlocking. The length of the osteophytes on each rim were quite regular. The breadth of the osteophytes, however, differed considerably. By describing these alterations, which can be described as 'normal' phenomena, this paper aims to contribute to increasing our knowledge of otters.

Keywords: *Lutra lutra*, otter, condylobasal length, postorbital constriction, baculum length, baculum weight, ventral bone-strip ischium, fibula fracture, arthrosis, osteophyte.

Introduction

On 24 April 2019 the remains of an otter (*Lutra lutra*) were found on the inland side on the verge of Road 606 on the island of Sula, on the north-western side of the Sognefjord, Norway (61°07'37"N 004°54'46"E, 12 m above sea level) (figure 1).

All of the recognisable skeletal elements were subsequently collected, resulting in the recovery of around 95% of the skeleton. Although speculative, it is estimated that more than nine months had elapsed between the individual's death and the skeleton being found.

After cleaning the remaining hairs from the skeleton, inspection revealed the characteristics of an adult specimen with several bone fractures of recent origin that may have led to its death, together with some lesions, including a healed fracture, arthrotic changes of different joints and bony outgrows (spurs or osteophytes) near the discal margins in several vertebrae.

Francois et al. (1995) define any bone out-

Figure 1. The location where the remains of an otter (*Lutra lutra*) were found on Sula (indicated by a red star), on the north-western side of the Sognefjord, Norway (from: Google Maps).

growth, but especially spurs around an osteoarthrotic joint, as an osteophyte. Macnab (1971) differentiates two types of osteophytes around vertebrae: the traction spur, with a shelf-like appearance, arising two millimetres or more from the discal margin, and the common marginal osteophyte. The latter is a claw-type spur, which has a broad base located at the discal margin and a claw-like configuration as it arches over the disc to eventually interlock with an opposing spur arising from an adjacent vertebra. While the marginal osteophyte seems to be related more to the collapse and loss of the width of the disc space, the traction spur appears to be primarily the result of abnormal motion. Both types of osteophytes, the claw-like as well as the shelf-like spur, are ossifications of the outermost annular fibers, some millimetres from the discal border (Macnab 1971). This paper describes the stages of development of the osteophytes on the vertebral margins, in accordance with the definitions by Morgan (1967), who studied the stages of osteophytes of the vertebrae in dogs (*Canis familiaris*). Stage one represented nodules (not ossified) located over intervertebral spaces and adjacent vertebral rims. Stage two consisted of small osteophytes on the vertebral margins. Stage three was characterised by larger bony projections with a cup shape but which did not extend beyond the vertebral end plate. Stage four was identified by the tip of the osteophytes extending beyond the edge of the vertebral body, without union between opposing osteophytes. In stage five bony fusion occurred between opposing osteophytes.

This paper attempts to estimate the age of the discovered specimen; describes the non-recent skeletal lesions and discusses its most probable cause of death.

The collected remains were added to the collection of the Dutch Natural History Museum in Rotterdam (Natuurhistorisch Museum Rotterdam) (NMR999000004336).

Material and methods

Heggberget (1984), observing histological sections of otter teeth, concluded that the number of dark-staining incremental cementum lines is a likely indicator of an otter's approximate age (in years). Hauer et al. (2000) presented an age pyramid of otters from eastern Germany based on the analysis of cementum annuli of canines (*n*=1027, males 58%) and concluded that only eight percent of the male otters were older than nine years, with the eldest specimen being over 15 years. However sectioning the teeth, requires the removal of a tooth and lessens the value of a skull for taxonomic purposes (Morris 1972). As a result, this destructive method was not applied in this investigation.

Dental wear has been used as a relative age indicator: the positive criterion for the oldest category (more than two - three years) is the exposure of the dentine of the upper first molar (Zeiler 1988). Another method of age determination is to examine the fusion of the epiphyseal line (*Cartilago physialis*[1]) of the postcranial bones. According to Zeiler (1988), the epiphyseal fusion in elderly otters can best be judged at the "narrow strip of bone at the ventral side of the ischium"; this line "remained unfused for up to 4-5 years in some cases. Only in animals older than 5 years was the fusion complete."

Van Bree et al. (1966) derived a set of parameters to determine the relative age of male otters: the condylobasal length and the postorbital constriction of the skull, and the length and weight of the baculum *(Os penis)*. They claimed to get reliable growth curves that can be used for relative age determinations, using a scatter diagram of the skull-index (postorbital constriction * condylobasal length^{-1}) and the baculum index (weight * length^{-1}). For the postorbital constriction lower values point to higher age categories, while for the other parameters higher values indicate older specimens.

Other parameters that can be helpful to distinguish otters within their first year of life from older ones, such as obliteration of cranial sutures, the size of the sagittal cranial crest and bone deposition around canine alveoles, are mentioned by Hauer et al. (2000).

To compare the present specimen, which was registered as NMR999000004336, with a larger dataset, besides the specimens described by Van Bree et al. (1966), some measurements of the skulls and bacula of other specimens are also included. These specimens came from the collections of the Natuurhistorisch Museum Rotterdam (NMR) (*n*=5) and one (skull only) from the collection of the Koninklijk Zeeuwsch Genootschap der Wetenschappen, Middelburg (KZGW). Of the specimens appended, one (NMR999000002556) came from Portugal, the others came from the Netherlands (table 1).

Following Hansen (1951, 1952) in this study each intervertebral space is identified by the serial number of its intervertebral disc, counted from the cranial to the caudal region. Between the skull and atlas (first cervical) there are two regular joints (without discs) and the atlas and the axis (the second cervical or epistropheus) cervical are connected by two regular joints. Therefore, the first intervertebral space with a disc (no. 1) is situated between the second and the third cervi-

[1] See note 1 of the *Nomina Anatomica Veterinaria*: "The Cartilago physialis is the plate of growing and calcifying cartilage between the Epiphysis and the Metaphysis during growth." (International Committee on Veterinary Gross Anatomical Nomenclature 2005).

Table 1. Characteristics of skulls and bacula of otter specimens from the collections of the NMR and KZGW. Abbreviations: CBL: condylobasal length, POC: postorbital constriction, LBAC: length of baculum, WBAC: weight of baculum, HCC: height of cranial crest, n.c.: not collected.*: in this specimen epiphyseal fusion was absent in all long bones, except for the proximal epiphyses of the fibulae.

Collection no.	CBL	POC	LBAC	WBAC	HCC
NMR999000001741	109.0 mm	13.0 mm	68.9 mm	2.8 g	1.4 mm
NMR999000002001	115.4 mm	18.1 mm	n.c.	n.c.	1.0 mm
NMR999000002556	114.7 mm	14.6 mm	n.c.	n.c.	1.3 mm
NMR999000003543*	120.2 mm	14.3 mm	> 40 mm	> 0.4 g	1.0 mm
NMR999000003675	119.4 mm	15.5 mm	62.0 mm	1.8	1.8 mm
NHG26170	119.6 mm	14.5 mm	n.c.	n.c.	2.0 mm

cal vertebra, and the following discs are numbered consecutively.

The perimeter of the vertebral margin was divided into four sectors that were designated as dorsal, ventral, right lateral, and left lateral (Morgan 1967). The distribution of the position of spurs on the vertebral margin was determined along its perimeter. In this study, bony outgrowths along the rim of the vertebral body were considered as one spur when they were separated by each other by clefts deeper than half of the least length of one of the neighbouring spurs.

The official terms used in international veterinary nomenclature follow the *Nomina Anatomica Veterinaria* (International Committee on Veterinary Gross Anatomical Nomenclature 2005) which has been followed in this paper. In order to avoid confusion by using terms with unclear meanings this article uses the glossary for rheumatic spinal diseases developed by François et al. (2005) for describing physiological conditions or pathological phenomena.

Results

Age estimation

The condylobasal length and the postorbital constriction of the skull of specimen NMR999000004336 measured 113.7 mm and 13.8 mm, respectively while the baculum measured 68.9 mm and weighed 3.9 g.

Figure 2 compares the parameters for the condylobasal length and postorbital constriction of this specimen with 80 male specimens from Denmark, the Netherlands and France. In these boxplots specimen NMR999000004336 is between the 25th and 75th percentile (both within the box), indicating that this animal had full-grown status.

Figure 3 shows box plots that rank the length and weight of the baculum of this specimen in comparison with 67 male specimens from Denmark, the Netherlands and France. In these boxplots specimen NMR999000004336 was ranked in the uppermost echelons, indicating a full-grown and a sexually mature status.

The maximal dimensions of the cranial crest of the recovered specimen (NMR999000004336) measured 3.6 mm, which when compared with the cranial crest dimensions of six other male otters (table 1), corroborates the impression the specimen was a fully-grown specimen. There were no visible cranial sutures (figure 5a).

The upper incisors and most of the upper premolars were evenly ground off. Both upper canines were also ground off at the tip of the dental crown exposing the dentin texture, while the attrition of the right one had almost

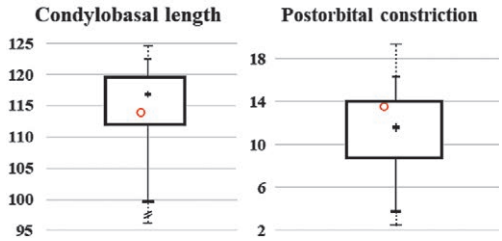

Figure 2. Boxplot of the condylobasal length (left) and the postorbital constriction (right), both based on 74 males, derived from Van Bree et al. (1966) supplemented with six additional specimens; the minimum condylobasal length is 61 mm. The position of specimen NMR999000004336 is marked with a red circle.

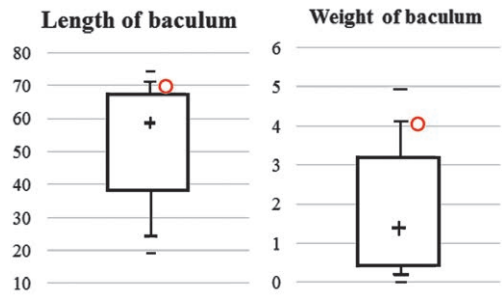

Figure 3. Boxplot of the length of the baculum based on 65 male specimens, derived from Van Bree et al. (1966) supplemented with two additional specimens. The position of specimen NMR999000004336 is marked with a red circle.

reached the pulp cavity (figure 5b). The left as well as the right fourth upper premolars showed a grinded ridge over the edge of the total length of the coronal cusp exposing the dentin texture. Both of the upper molars were heavily grinded, and the left one was partially fractured, exposing a cavity with grinded edges. Both third lower incisors were grinded: the central and middle lower incisors on the right side were fractured (and worn) and those on the left side were evenly worn down. Both lower canines were also heavily grinded at the tips, the right one even exposing a pinhole connection to the pulp cavity. The lower unicuspid premolars all were grinded, the right one more than the left, while the crown of the left second premolar was fractured and the remaining posterior root showed a ground surface. The fourth lower premolars had ground ridges over the whole length and the lower molars were ground to a lesser extent.

A comparison of this pattern of dental wear with the mandibular tooth-wear pattern used by Zeiler (1988), suggests that this otter specimen was at least three years old.

All the epiphyseal lines, were completely fused, except the strip at the ventral side of the ischium, indicating an age of 4-5 years (figure 4).

Fractures

Fractures, without any signs of healing were present on two left ribs (C5 & C13) and thirteen of the right ribs (C2C14). The tips of the spinal processes of the 4th to 7th cervical vertebrae and the 1st to 3rd and 5th thoracic vertebrae were fractured. The spinal processes of the 5th and 6th lumbar vertebrae were also fractured, with the distal fragments still attached and clearly bent towards the left side. The left scapula was fractured in seven parts, while the right one had a longitudinal fissure in the caudal part of the spine of the scapula. The outline of the shaft of the left fibula showed a fusiform thickening and, on close observation, a healed longitudinal fracture was detected (figure 6).

Arthrosis

The right femur showed a slight proliferation of the edge of the medial and lateral condyles, with the articular surface left intact. The distal part of the left femur exhibited proliferation at the rim of the anterolateral and anteromedial

Figure 4. Part of the left pelvis of the recovered otter (ventral view). The unfused strip was attached to the ischium at the Ramus ossis ischii (see also note 56 of the N.A.V.[2]).

condyles. The medial plateau of the right tibia had several circular pits, varying in diameter. On the left tibia an almost circular osseous proliferation was attached to the rim of the articular surface of the plateau. The lesion of the articular surface could be described as severe arthrosis deformans (figure 7). Large calcifications of tendon attachments (enthesophytes) were found on the dorsal side of the proximal end of the left tibia, and the proximal side of the left fibula was completely fixed with proliferations of the tibia. The right fibula showed a slight proliferation at the connection with the tibia on the proximal side.

Both of the humeri were without arthrotic signs, however the left ulna and each caput radii showed minimal arthrotic reactions around the rims of the proximal radioulnar joints.

Osteophytes

Several of the thoracic vertebrae showed extended new bulging at the rims, which were most prominent in the caudal thoracic vertebrae. There was erosion of the epiphysis on the thoracic vertebrae, bordering intervertebral space 19 (figure 8). Several thoracic vertebrae had spurs on the rims of the intervertebral spaces: light, stage II (intervertebral space 9), intermediate with kissing spines, stage III (intervertebral space 16) and severe, with interlocked spines, stage IV (intervertebral space 19) (stages after Morgan 1967) (figure 8).

The vertebrae affected with these types of spurs were positioned well before and after the transition zone of the anticlinal vertebra (*Vertebra anticlinalis*)[3], while the centre of this zone was free from these types of spurs (figure 9).

The length of the osteophytes on each rim were quite regular: the spurs along the same rim had similar measurements. The breadth of the osteophytes, however, differed considerably. The length of the spurs on the vertebral margin along the perimeter of the 9th, 16th and 19th intervertebral spaces was most prominent

[2] Note 56 of the *Nomina Anatomica Veterinaria*: "*Corpus ossis ischii, Ramus ossis ischii*. According to the N.A., Ramus ossis ischii denotes the part that was previously called Ramus symphysialis by veterinary anatomists. The qualifying "symphysialis" is now unneccesary because there is only one Ramus; the former Ramus acetabularis is included in the Corpus ossis ischii" (International Committee on Veterinary Gross Anatomical Nomenclature 2005).

[3] See note 38 of the *Nomina Anatomica Veterinaria*: *Vertebra anticlinalis*. This is the first vertebra in the caudal thoracic or lumbar region that has its Processus spinosus perpendicular to the body of the vertebra (International Committee on Veterinary Gross Anatomical Nomenclature 2005).

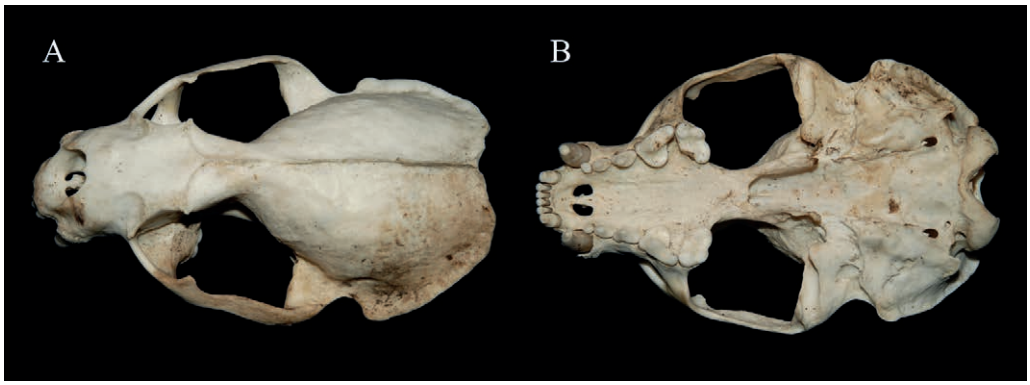

Figure 5. Skull of the recovered otter. A. Dorsal view. Note the absence of cranial sutures and the bone deposition around canine alveoles. B. Ventral view. Note the abrasion of the tip of the dental crowns exposing the dentin texture.

Figure 6. The left tibia and fibula complex of the recovered otter (*Lutra lutra*) with the remains of a longitudinal fracture surrounded by callus leading to a fusiform thickening of the fibula.

in the lateral sector and less so in the ventral sector; there were no spurs in the dorsal sector of the rims.

The margins of the caudal and cranial vertebral extremities facing the 17th, 18th and 20th intervertebral spaces presented the onset of shelf-like osteophytes which were irregular in length (measuring at most 1.3 mm).

At the cranial side of the sacral-caudal transition (intervertebral space 29) two continuous, shelf-like osteophytes were present on the left and right lateral sides. At the caudal side of this intervertebral space, one continuous shelf-like osteophyte was visible at the lateral and ventral sectors, with only the dorsal sector remaining free of osteophytes.

There were no signs of arthrosis of the costovertebral joints on the thoracic vertebrae, whereas on the superior parts of the zygapophyseal joints of the 2nd to 5th and 8th to 13th thoracic vertebrae only minor erosions were present. Minimal, symmetrical, osteal reactions were present at the caudal rims of the sacroiliac joints.

Discussion

Reading the values of the scatter diagrams from figures 1 and 2 in Van Bree et al. (1966) casts doubts on the relevance of using skull measurements (condylobasal length and postorbital constriction) for age estimations: the correlations of these measurements for male otter skulls could be calculated as – 0.57 for specimens from Denmark (n=41) and – 0.61 for specimens from the Netherlands (n=33). The negative value of these coefficients is due to postorbital constriction lessening in higher age categories. Correlations of the scatter dia-

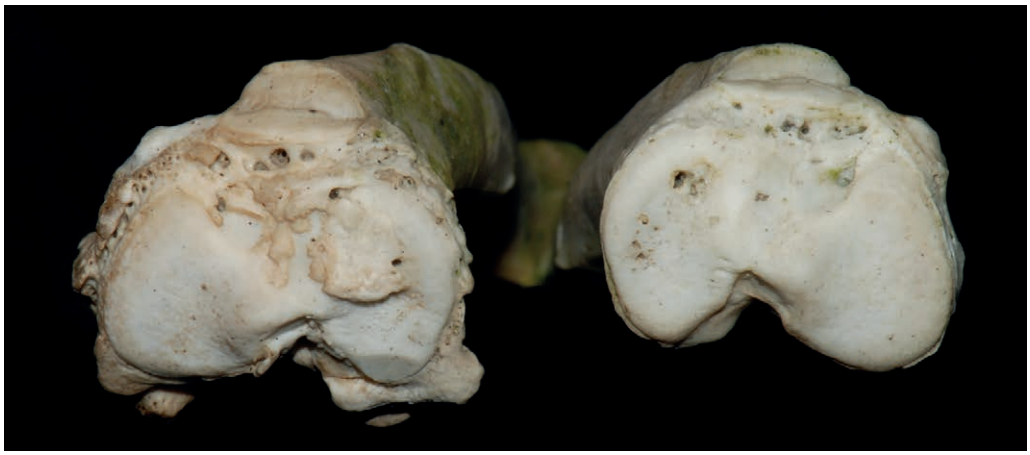

Figure 7. Proximal view of the left and right tibia plateau of the recovered otter (*Lutra lutra*). Note the severe arthrosis deformans around the left plateau (described in the text).

gram in figure 3 in Van Bree et al. (1966) of the length and the weight of bacula are much stronger for the combined specimens from Denmark (*n*=43), the Netherlands (*n*=10) and France (*n*=12), this correlation was calculated at 0.93. High values of condylobasal length do not seem to be an excellent predictor for old age in specimen NMR999000003543* (see table 1), although the condylobasal length equalled 120.2 mm, the epiphysis was not fused with the diaphysis in the long bones, except proximally in the fibulae. According to Zeiler (1988) epiphyseal fusion status of specimen NMR999000003543 would give it an age of barely two years.

The age of the described otter is not precisely known, however comparing the measurements of all age-related characteristics, apart from the condylobasal length and postorbital constriction with measurements of large groups (*n*=81, *n*=67), clearly indicates this specimen to be fully mature. The other skull parameter, the height of cranial crest, reaches the highest value of a rather limited number (see table 1). The wearing of the teeth, especially of canines and molars, suggests that the specimen was at least three years old. Based on the epiphyseal lines, which were all completely fused, except the strip on the ventral side of the ischium, the specimen's age can be estimated as between 4 to 5 years.

Heggberget (1984) mentions that there have been no studies done which have managed to establish the true age classes over the whole age spectre of a wild population of otter. Later on, Hauer et al. (2000) presented an age pyramid in their study of otters in eastern Germany over the period 1957 to 1998, however this was biased, as it was predominantly based (69%) on traffic victims. Kruuk et al. (1997) found a change of mean age in Scottish otters based on an increasing proportion of immature otters. Since the reintroduction of otters in the Netherlands in 2002 the population has steadily increased (Lammertsma & Niewold 2016), an increase which should be reflected in higher age categories. Recognition of elderly specimens is therefore important, as these could indicate a stable population (Hauer et al. 2000).

The recent fractures of ribs, scapulae and vertebrae observed in the retrieved otter specimen are most likely the results of a traffic accident that lead to death of the specimen. Also the location of the remains on the road verge supports this supposition. Jancke & Giere (2011) found most otter road accidents in Uckermark County (Brandenburg, north-east Germany) were located close to one or more lakes. In this case here, the road

Figure 8. Caudal (left) and cranial (right) views at the 9th, 16th and 19th intervertebral spaces. Note the bony protuberances (stages III and IV, after Morgan) at the margins of the caudal and cranial sides of the vertebral bodies. The epiphyseal surfaces themselves are rather smooth, only the vertebrae bordering intervertebral space no. 19 showed signs of erosion.

Figure 9. Left lateral view of the spinal column of the recovered otter (*Lutra lutra*) around the transition zone (t) of the diaphragmatic (left of 't') and anticlinal vertebra (right of 't') which have backward and forward sloping spinous processes respectively. Arrows indicate the osteophytes at the 16th and 19th intervertebral space (left and right respectively).

verge where the specimen was found was 21m away from the shoreline of the fjord. Jancke & Giere (2011) also found an almost linear relationship between the maximum permitted speed for motor vehicles (between 30 km/h and 100 km/h.) and the number of otters killed. Although the physical characteristics of road 606 at the spot of specimen retrieval (an unclear bend, near the top of the hill) would limit the speed of motor vehicles to 40-50 km/h, the limited vegetative cover along the road suggest either a direct hit or a return of the disturbed animal to the road, ending up with the fatal collision.

The extra formation of bone (callus) on the left fibula is the typical end stage of a healed fracture, suggesting that this fracture occurred at least several months before the animal's death. Healed fractures in feral mammals are quite regularly encountered: living in the wild can be risky. In otters traumatic injuries, principally caused by road traffic accidents and intra-specific aggression, also are common (Simpson 1997). The cause of the fibula fracture in this case is not likely to be the consequence of a road accident: the impact of a motor vehicle on a hind leg would be too massive to be restricted just a fracture of the fibula and not of the tibia. Intra-specific bite wounds are usually to the face, feet and anus/genitals (Simpson & Coxon 2000). Based on these finds and observations, it is quite possible the fibula fracture originated from such an intra-specific aggression encounter which subsequently healed.

The asymmetrical affection, predominant on the left side of the arthrosis of the tibiae (and, on a more modest level of the femora), hints to its origin: the fibular fracture would have caused a limping movement for a longer time, perhaps permanently. This condition ended up in severe arthrosis deformans.

The degenerative process at the thoracic vertebrae – the erosion of the endplates, osteophytes till the stages of interlocking and shelf formation – also illustrates the condition of this specimen. In other mammal species (e.g. dogs) the prevalence of spondylarthrosis (spondylosis deformans) accompanied by osteophytes is common among elderly specimens (Morgan 1967). It is plausible, but not certain, that there is a causative relation between the fibula fracture and the arthrotic knee on the left side. However, claiming a relation between the impaired movements, caused by the left hindquarter and the development of vertebral alterations in this otter specimen, is still speculative.

The prevalence of different appearances of arthrosis deformans in otters is unknown. Until now no cases of arthrotic malformations in otters have been described in the literature (see e.g. Gulland et al. 2018). Alterations, eventually accompanied by arthrosis deformans, seem to be considered as just a 'normal' phenomenon and perhaps for that

reason have not previously been described (Anonymous 2004). This case gives a good opportunity to fill up part of this lacuna.

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Samenvatting

Skelet van een otter (*Lutra lutra*) met enkele gewone en opmerkelijke veranderingen

Op 24 april 2019 werden op het eiland Sula, aan de uiterste noordwestkant van het Sognefjord (Noorwegen), de overblijfselen van een otter (*Lutra lutra*) gevonden langs de kant

van de weg. Ongeveer 95% van de skeletelementen werd verzameld. Inspectie bracht verschillende gebroken ribben en wervels van recente oorsprong aan het licht, die ongetwijfeld de dood van dit exemplaar veroorzaakten. Op basis van schedelmetingen en lengte- en gewichtsmetingen van het penisbot kon het gevonden specimen worden beschreven als een volwassen mannetje. Slijtage van de tanden en kiezen wezen op een geschatte leeftijd van meer dan drie jaar. Aan de hand van een nog losliggende smalle strip bot, dat nog niet was vastgegroeid aan de onderzijde van het bekken, was het mogelijk de leeftijd nauwkeuriger in te schatten op vier tot vijf jaar.

Naast een genezen botbreuk van de schacht van het linker kuitbeen, werd bij het linker kniegewricht een ernstige artrose gevonden. Zo vertoonde het linker scheenbeen uitgebreide botwoekeringen op het gewrichtsplateau met daarnaast ook erosies ten gevolge van slijtage. Verder waren de peesaanhechtingen aan de achterzijde gedeeltelijk verkalkt. Beide dijbeenderen onthulden aan de gewrichtsknobbels botwoekeringen, in het bijzonder aan de linkerkant. De borstwervels vertoonden erosies ten gevolge van slijtage van de eindplaten en slijtage verschijnselen van andere borstwervelgewrichten. Aan de randen van de tussenwervelruimten 9, 16 en 19 werden diverse stadia van haakvormige uitgroeiingen vastgesteld, in de laatste met in elkaar grijpende vergroeiingen. De lengte van de uitgroeiingen op elke rand was vrij regelmatig, de breedte verschilde echter aanzienlijk. De uitgroeiingen op de wervelkolom langs de omtrek bij alle drie tussenwervelruimten waren het meest duidelijk in de zijwaarts gerichte sectoren, minder in de ventrale delen en afwezig in het rugwaartse deel van de randen. Het beschrijven van de gevonden afwijkingen, die als 'gewone' vondsten afgedaan zouden kunnen worden, is van belang omdat deze veel voorkomende afwijkingen kunnen bijdragen aan het correct duiden van de leeftijd van individuele dieren. Deze vaardigheid is noodzakelijk voor het juist beoordelen van de leeftijdsopbouw van populaties otters.

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