On the occurrence of spondylosis deformans in white-beaked dolphins *Lagenorhynchus albirostris* (Gray, 1846) stranded on the Dutch coast

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Key words: Spondylosis deformans; *Lagenorhynchus albirostris*; Cetacea; The Netherlands.
Fourty-three skeletons of *Lagenorhynchus albirostris* were examined for the occurrence of pathological changes in the vertebral column. In comparison, 83 skeletons of *Phocoena phocoena* and 18 of *Tursiops truncatus* were studied. The pathogenesis of spondylosis deformans is discussed.

Introduction

Most pathological deformations of the vertebral column in Cetacea can be diagnosed as spondylosis deformans. Spondylosis deformans is a degenerative disease of the intervertebral disc and its surrounding structures, found in man and other mammals of advancing age.

A recent survey through the collections of the National Museum of Natural History, Leiden (RMNH = Rijksmuseum van Natuurlijke Historie), and the Zoological Museum, Amsterdam (ZMA) in the Netherlands revealed several cases of this disease in white-beaked dolphins *Lagenorhynchus albirostris* (Gray, 1846) stranded on the Dutch coast. An autopsy on a fresh white-beaked dolphin confirmed degeneration of the intervertebral discs.

The occurrence of osteophytes (new bone formation, osseous spurs growing so as to form lips around the affected joint) in the vertebral column of Cetacea is well-known. The condition is described under different names in the cetological literature, mostly as spondylitis deformans which is, however, incorrect. Since degeneration of the intervertebral disc plays a major role in the development of the pathological changes in most cases, the correct name for this disease is spondylosis deformans (Kompanje, 1993).

In the vertebral column of mammals, the discus intervertebralis and the adjacent vertebral corpora form a false joint, formed in the centre by the nucleus pulposus, at the periphery by the annulus fibrosus. This discus is separated from the adjacent corpora by thin plates of hyaline cartilage (cartilaginous end-plates). The annulus fibrosus is the major part of the intervertebral disc and consists of fibrocartilaginous fibres. The nucleus pulposus looks like a white, semi-liquid substance (fig. 9). At a young age the nucleus is clearly separated from the annulus, but with advancing years it gradually becomes inseparable from the latter. The content of water in the nucleus is high, but decreases with age. The nucleus is normally under pressure and is quite vulnerable to degeneration. Osteophytes tend to develop wherever the pressure is greatest (Nathan 1962). The incidence of pathological changes of the intervertebral disc increases gradually with age. So, in short, the combination of the semi-liquid nucleus pulposus, situated in the middle of the hyaline cartilage between the bodies of two vertebrae with the annulus fibrosus at its periphery, provides a cushion between the two vertebral bodies and permits slight movement between them. Unfortunately, intervertebral discs can suffer of degenerative changes that interfere with their normal supportive function.

Four stages of degeneration can be distinguished (Sager 1969). In the first, there is a mild to moderate degeneration of the discus. The height of the discus is reduced and white collagen lamellae are readily distinguished. At the periphery small osteophytes are visible where fibres are attached to the bone. The nucleus changes into a fibrocartilaginous mass. There is no clear perforation of the covering bony plates of the vertebrae (fig. 2). The second stage shows a moderate to moderately severe degeneration, with extensive, degenerative changes in the annulus and nucleus. The nucleus has become completely transformed into fibrous tissue and there is necrosis of the cartilage, as well as the formation of marginal osteophytes and a pathological perforation of the covering bony plates (fig. 3). In stage three, there are pronounced degenerative changes of the annulus and nucleus. No normal structures are left and usually, uncovered bone is visible. Large osteophytes can be seen at the periphery. The whole vertebral plate is covered with pathological perforations and new bone formation (fig. 4). The most severe form of degeneration is seen in stage four, when ankylosis between two adjacent vertebrae occurs. Movement is no longer possible. The final stage of degeneration is a solidly fused block of vertebrae (fig. 5).

The osteophytes too, can be (arbitrarily) separated into four grades after Nathan (1962). In grade 1, only small hyperostoses are found. In grade 2, there is protrusion of bone in a horizontal direction (fig. 2). In grade 3, the osteophytes have a characteristic parrot-beak shape. The free end of the osteophyte curves away from the discus. The osteophytes of adjacent vertebrae may impinge on each other (fig. 8). In grade 4, ankylosis between the osteophytes of adjacent vertebrae has developed (figs. 5 & 8).

Incidence of spondylosis deformans

A total of 43 skeletons of white-beaked dolphins of known sex were examined for the occurrence of pathological changes in the vertebral column. In comparison, 85 skeletons of harbour porpoises *Phocoena phocoena* (Linnaeus, 1758) and 18 skeletons of bottlenose dolphins *Tursiops truncatus* (Montagu, 1821) of known sex were studied (table 1). The vertebral column and intervertebral discs of a fresh dead female white-beaked dolphin could be studied.

Separation between immature and adult animals was made by looking at the maturity of the vertebral body. In immature animals, both vertebral end-plates were separable from the bodies of all thoracic and lumbar, and of most caudal vertebrae.

The vertebral column can be divided into four (five) regions: cervical, thoracic, lumbar (and sacral) and caudal. The first two cervical vertebrae are normally fused. The marginal ridges of the other cervical vertebrae are often irregular, so it is difficult to recognize pathological osteophytes in this region. For this reason, the cervical region is excluded from the present study. Nevertheless, pathological changes of the cervical vertebrae (sclerosis, ankylosis) can be observed.

Lagenorhynchus albirostris (Gray, 1846)

Material.— 13.x.1929. (RMNH 31207) stranded on the island of Texel, province of Noord-Holland (Van Deinse 1931: 270; Van Bree & Nijssen 1964: 86).- 8.viii.1941. ♂ (RMNH 4523) stranded at Wieringen, province of Noord-Holland (Van Deinse 1946: 191-192; Van Bree & Nijssen 1964: 86).- 5.v.1964. ♀ (ZMA 6815) stranded on the island of Texel, province of Noord-Holland (Van Bree & Nijssen 1964: 85-93, fig. 3; Van Deinse 1966: 23).- 5.v.1964. ♀ (RMNH 17847) stranded on the island of Texel, province of Noord-Holland (Van Bree & Nijssen 1964: 85-93; Van Deinse 1966: 23).- 4.xi.1964. ♀ (RMNH 17968) stranded on the island of Terschelling, province of Friesland (Van Deinse 1966: 23).- 14.ii.1965. ♀ (RMNH 18067) stranded at Katwijk aan Zee, province of Zuid-Holland.- 19.i.1968. ♂ (ZMA 11.368) stranded on the island of Schiermonnikoog, province of Friesland (Van Bree & Duguy 1970: 13-14, fig. 3).- 20.vii.1969. ♀ (RMNH 21046) stranded between Kijkduin and Scheveningen, province of Zuid-Holland.- 15.iv.1970. ♀ (ZMA 12.982) stranded at IJmuiden, province of Noord-Holland (Husson & Van Bree 1972: 3).- 23.xi.1974. (ZMA 17.232) stranded on the island of Terschelling, province of Friesland (Van Assen 1975: 63-64; Husson & Van Bree 1976: 27).-28.xi.1974. ♀♀ (ZMA 17.230 & 17.231) stranded 2 km north of Egmond aan Zee, province of Noord-Holland (Husson & Van Bree 1976: 27).- 21.i.1976. ♀ (ZMA 18.150) stranded at St. Jacobi Parochie, province of Friesland (Van Bree & Smeenk 1978: 14).- 24.i.1976. ♂ (RMNH 25029) stranded on the island of Schiermonnikoog, province of Friesland (Van Bree & Smeenk 1978: 14).- 26.iv.1976. ♀ (RMNH 25152) stranded at Wassenaarseslag, province of Zuid-Holland (Van Bree & Smeenk 1978: 14).- 14.xi.1981. ♀ (RMNH 30513) stranded at Renesse, province of Zeeland (Smeenk 1986: 273).- 2.ii.1983. ♂ (RMNH 33038) stranded at Den Helder, province of Noord-Holland (Smeenk 1986: 279).- 13.v.1983. ♀ (RMNH 32233) stranded on the island of Texel, province of Noord-Holland (Smeenk 1986: 279, fig. 3).- 30.i.1986. ♀ (RMNH 35130) stranded on the island of Ameland, province of Friesland (Smeenk 1989: 177).- 28.ii.1993. ♀ (RMNH 38415) found drifting in the Marsdiep, province of Noord-Holland.

Table 1. Distribution of 146 studied vertebral columns according to species, age, sex and incidence of spondylosis deformans. Skeletons with unknown sex are not included in this table.

Species	age	sex	total number	number with spondylosis deformans	%
Lagenorhynchus albirostris	ad.	♂	7	3	42
Lagenorhynchus albirostris	ad.	♀	22	12	54
Lagenorhynchus albirostris	imm.	♂	6	0	0
Lagenorhynchus albirostris	imm.	♀	8	0	0
Phocoena phocoena	ad.	♂	19	0	0
Phocoena phocoena	ad.	♀	29	1	3
Phocoena phocoena	imm.	♂	17	0	0
Phocoena phocoena	imm.	♀	20	0	0
Tursiops truncatus	ad.	♂	5	0	0
Tursiops truncatus	ad.	♀	9	1	1
Tursiops truncatus	imm.	♂	3	0	0
Tursiops truncatus	imm.	♀	1	0	0

It is evident that pathological changes consistent with spondylosis deformans occur quite often in adult white-beaked dolphins, but only occasionally in bottlenose dolphins and harbour porpoises.

Six out of 12 ♀ and 2 out of 3 ♂ white-beaked dolphins had pathological changes in all three regions (fig. 6). Three ♀ had lesions in the lumbar/caudal regions, in 2 ♀

deformations occurred in the thoracic and caudal regions and 1 ♀ and 1 ♂ showed lesions in the thoracic and lumbar regions. Ankylosis of two or more vertebrae occurred mostly in the lumbar and caudal regions of the ♀ dolphins (n= 8 lumbar, 7 caudal, 1 thoracic).

Ankylosis was found in the thoracic region of one ♂, but this was partly the result of osteomyelitis of the vertebral body. Osteophytes occurred equally in all regions (thoracic 3 ♂, 8 ♀; lumbar 3 ♂, 7 ♀ and caudal 2 ♂, 9 ♀). Lipping of 'parrot-beak'-osteophytes or spondylosis stage 3 was mostly found in the lumbar region (thoracic 0 ♂, 2 ♀; lumbar 1 ♂, 5 ♀ and caudal 0 ♂, 0 ♀). In general, the lesions seem to be more severely in female dolphins.

Severe pathological changes of the vertebrae were found in the skeleton of the white-beaked dolphin of unknown sex, found 23 November 1974 on the island of Terschelling (ZMA 17.232) (Van Assen 1975). Ankylosis of the 4th to 10th lumbar vertebrae (fig. 8) and a kyphosis from the 12th lumbar to the 17th caudal vertebra had occurred (figs 7, 12). This kyphosis, however, is not related to degenerative changes of the intervertebral discs. Slijper (1936) described a similar case in a white-beaked dolphin killed in the harbour of Peterhead (Scotland) on 29 August 1933, in which a kyphosis was found from the 5th lumbar to the 18th caudal vertebra. Slijper considered this a congenital deformation, which seems plausible. In the dolphin from Terschelling too, the pathological changes must have developed at an ealy age, as can be deduced from the deformations of the transverse processes due to muscle-traction (fig. 12). The dolphin had become quite old with these deformations, judging from the pathological changes of the spinous and tranverse processes and the occurrence of a severe spondylosis deformans.

Vertebral osteophytes and destruction of vertebral bodies most probably due to infection were found in four harbour porpoises and one bottlenose dolphin.

Discussion

Stranded Delphinidae and other Odontocetes are often in a bad physical condition (De Smet 1977; Van Nie 1989; Baker & Martin 1992; Baker 1992). De Smet (1977) studied skeletons of bottlenose dolphins and got the impression that tooth diseases, rib fractures and spondylosis are common in aged animals.

Individual cases of spondylosis deformans in white-beaked dolphins are described by Slijper (1936), Van Bree & Nijssen (1964), Van Bree & Duguy (1970) and De Smet (1972). Walker et al. (1986) examined 63 skeletons of Pacific white-sited dolphins *Lagenorhynchus obliquidens* Gill,1865 for pathological changes. Of these, 34 (54%) demonstrated some degree of vertebral bone disease, which the authors called osteonecrosis.

All four typical stages of degeneration, macroscopic bone changes and the four types of osteophytes were recognized in the diseased vertebrae of the studied skeletons of adult white-beaked dolphins, so the diagnosis of disc degeneration followed by spondylosis deformans seems correct in all these cases. Unfortunately, detailed autopsy reports are lacking. Hence, nothing can be said about the health status of these animals.

All stages of degeneration were also found in a physically healthy, pregnant female white-beaked dolphin, which was found dead floating in the Marsdiep near the island of Texel on 28 February 1993. Necrosis of the nucleus pulposus, degeneration and sclerosis of the vertebral bony plates and ankylosis of two or more vertebrae were found in the thoracic and lumbar vertebrae during the autopsy (figs 9-11).

Slijper (1936) and Kinze (1986) suggested that spondylosis deformans in various species of odontoceti can be found at all ages and that the disease is not restricted to old animals. Slijper examined several species, including white-beaked dolphins. Kinze examined skeletons of harbour porpoises. However, no traces of spondylosis were found in the 14 immature white-beaked dolphins studied here, nor in the immature harbour porpoises and bottlenose dolphins (table 1). Since spondylosis is a degenerative disease, this is not surprising. In man, spondylosis does not occur before the age of 20 years (Nathan 1962; Sager 1969; Marcove & Arlen 1992). In man, osteophyte formation, not related to bacterial infection, appears when disc degeneration begins to develop and epiphyseal osteogenetic activity ceases (Bick & Copel 1950; Nathan 1962). Nevertheless, I found pathological changes in 5 lumbar vertebrae of one immature female white-beaked dolphin (RMNH 32233), at first sight resembling spondylosis deformans (figs 13-14). In one of these vertebrae, traces of osteomyelitis with cloacae and fistulae were present. Also, pathological deformation in the laminae and transverse processes was found, which is atypical for spondylosis deformans. Developing bony tissue of immature animals reacts strongly to infection. Any pathological process affecting the vertebrae may lead to the formation of osteophytes. In this particular animal, the changes seem to be related to a bacterial infection of the intervertebral disc and the adjacent vertebral plate (spondylo-discitis) or a bacterial osteomyelitis of the vertebrae due to direct infection after a penetrating trauma. Destruction of the intervertebral disc due to infection leads to the formation of sometimes bizarre osteophytes. The deformations in the vertebrae of this immature dolphin are very similar to those of the vertebrae of the (immature) harbour porpoise described by Kinze (1986), diagnosed as spondylitis deformans. Destruction of the vertebral body and irregular osteophytes are also seen in the second and third thoracic vertebrae of a female harbour porpoise (RMNH 28590) found at Cadzand and in two other harbour porpoises. A diagnosis of spondylo-discitis with osteomyelitis seems more likely in these five cases.

Conclusions

One may conclude that spondylosis deformans occurs quite often in white-beaked dolphins of advanced age, most frequently in the ventral part of the vertebral bodies in the lumbar/caudal region. In harbour porpoises and bottlenose dolphins, which were studied in comparison, the disease was hardly found. The occurrence of these deformations is not restricted to animals in a bad physical condition. The disease seems to occur mainly and most severely in female dolphins. Spondylosis deformans is restricted to aged animals, since it is degeneration of the intravertebral discs that causes the deformations. Deformations of the vertebrae in immature dolphins, resembling spondylosis deformans, are most likely the result of spondylo-discitis with osteomyelitis of the vertebral body, or of complications after a local infection of the vertebrae.

Why white-beaked dolphins appear much more vulnerable to spondylosis deformans than the other odontocetes examined is hard to say. The white-beaked dolphin is the largest species in the genus *Lagenorhynchus*, with a very robust and bulky body, which gives more resistance during fast swimming than a slender body, resulting in more pressure on the vertebral column. It is also the dolphin with the largest number of vertebrae (88-93), only surpassed by Dall's porpoise *Phocoenoides dalli* (True, 1885), with 92-98 vertebrae. By comparison, the bottlenose dolphin *Tursiops truncatus* has c. 65 vertebrae and the harbour porpoise c. 68 (Tinker 1988). White-beaked dolphins are energetic surfers and jumpers and fast swimmers. Jumps of over 5 m high have been observed, after which the animal often hits the water on its side (Baptist 1987). In Newfoundland the species is also known as "spinner" (Ellis 1983). Hypothetically, these three factors (bulky body, large number of vertebrae and fast swimming and frequent jumping) may render this species more vulnerable to spondylosis deformans. In man, spondylosis is observed more frequently in individuals doing heavy manual labour (Nathan 1962; Marcove & Arlen 1992). Further, genetic disposition may play a part.

During this survey its was significant that only few other pathological lesions were found in the examined skeletons of white-beaked dolphins. Many of the aged dolphins were suffering from tooth abrasion and tooth loss. Healed rib fractures were found in two animals (♀ ZMA 6815 and ♀ RMNH 17968). In one dolphin (♀ RMNH 21046) a broken mandible with secondary osteomyelitis was found.

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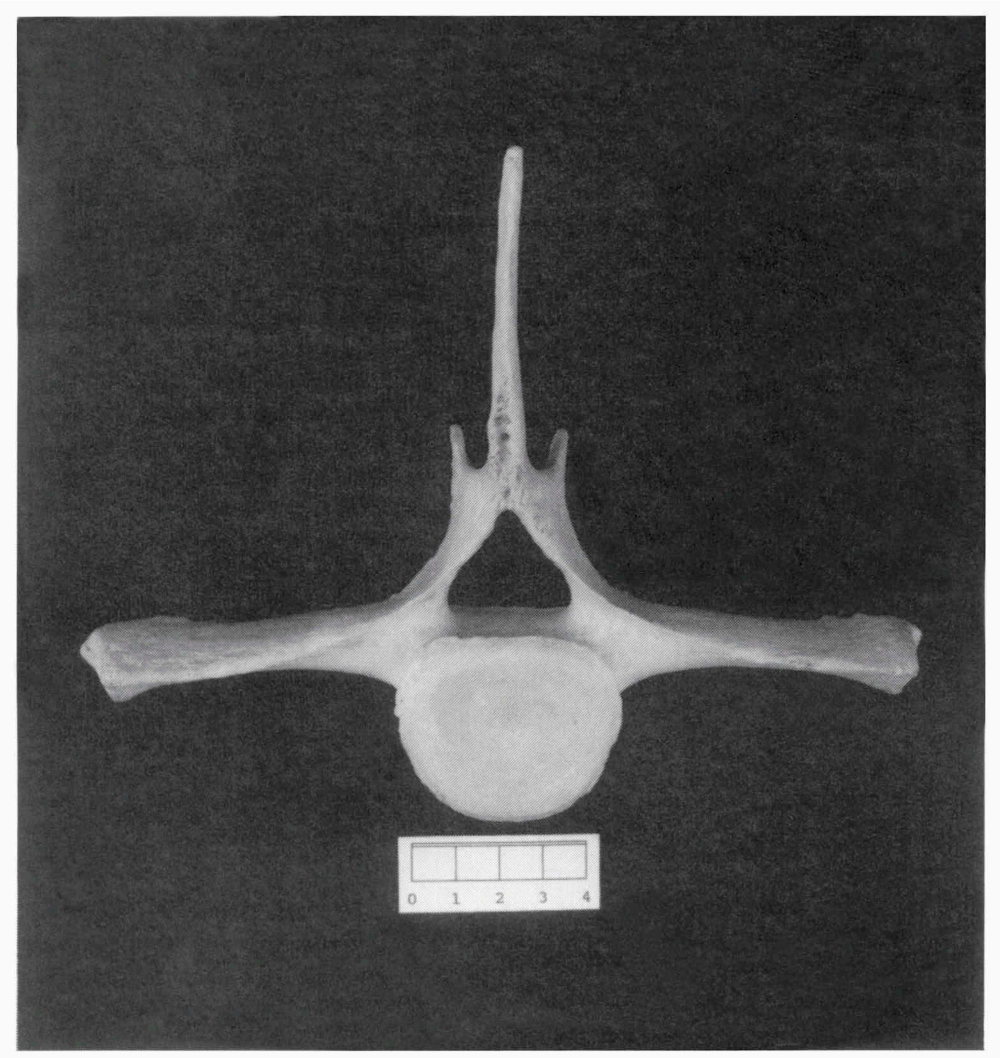

Fig. 1. *Lagenorhynchus albirostris*, normal thoracic vertebra (adult ♀, RMNH 18067) (Mr R. 't Hart).

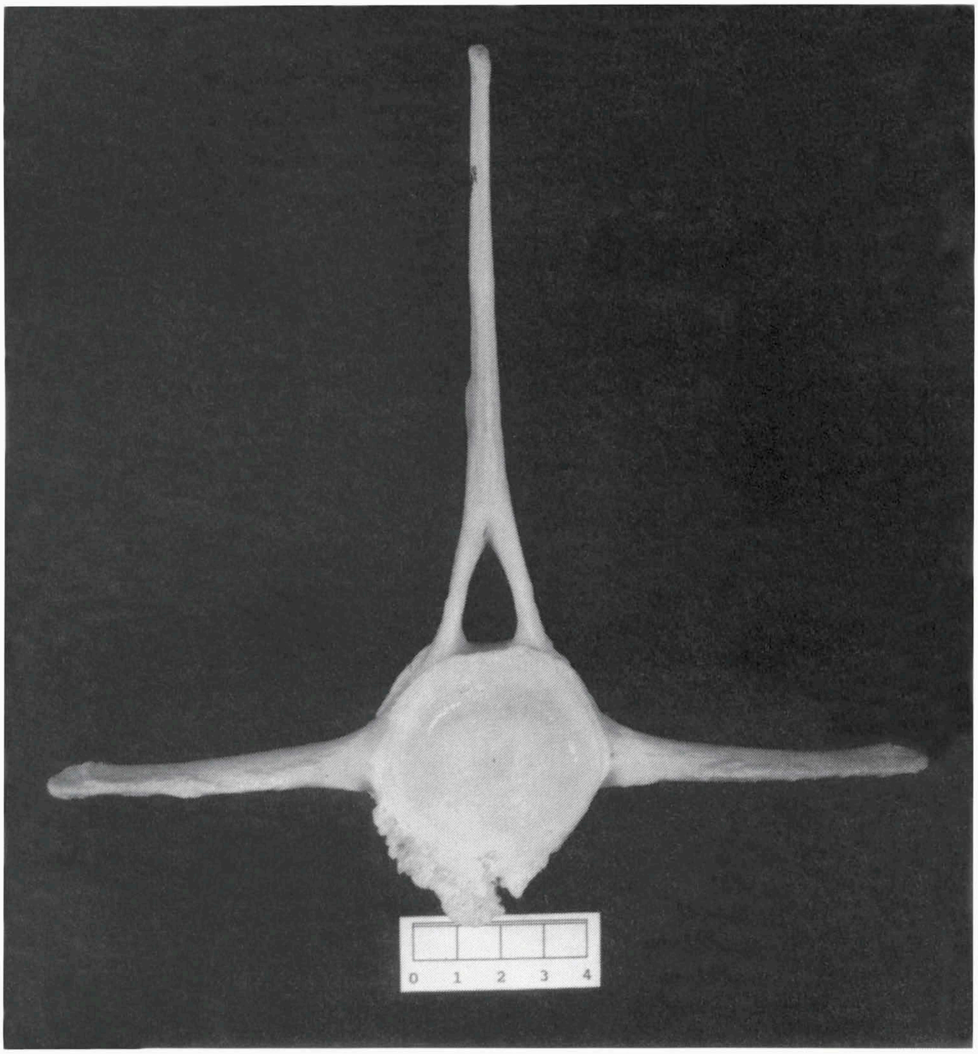

Fig. 2. *Lagenorhynchus albirostris*, marginal osteophytes on a lumbar vertebra (adult ♀, RMNH 18067) (Mr R. 't Hart).

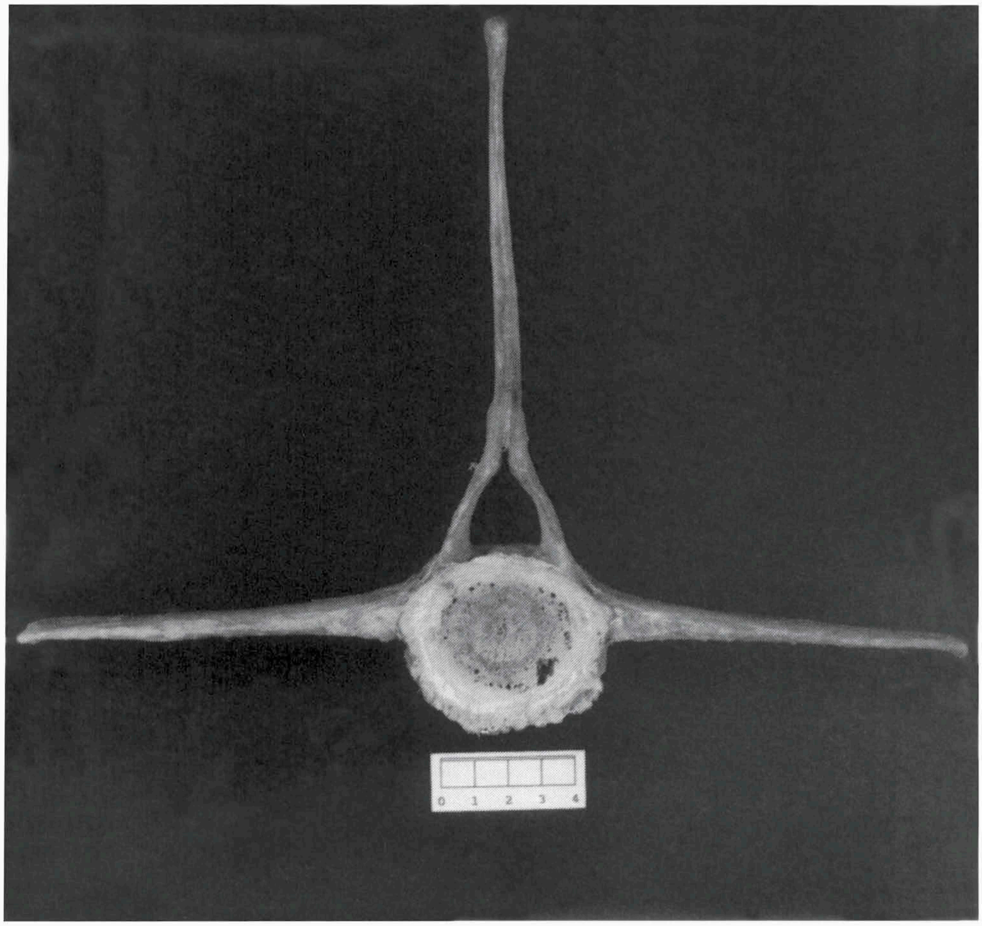

Fig. 3. *Lagenorhynchus albirostris*, lumbar vertebra with marginal osteophytes and pathological perforations of the bony vertebral plate (adult ♀, ZMA 17.230) (Mr R. 't Hart).

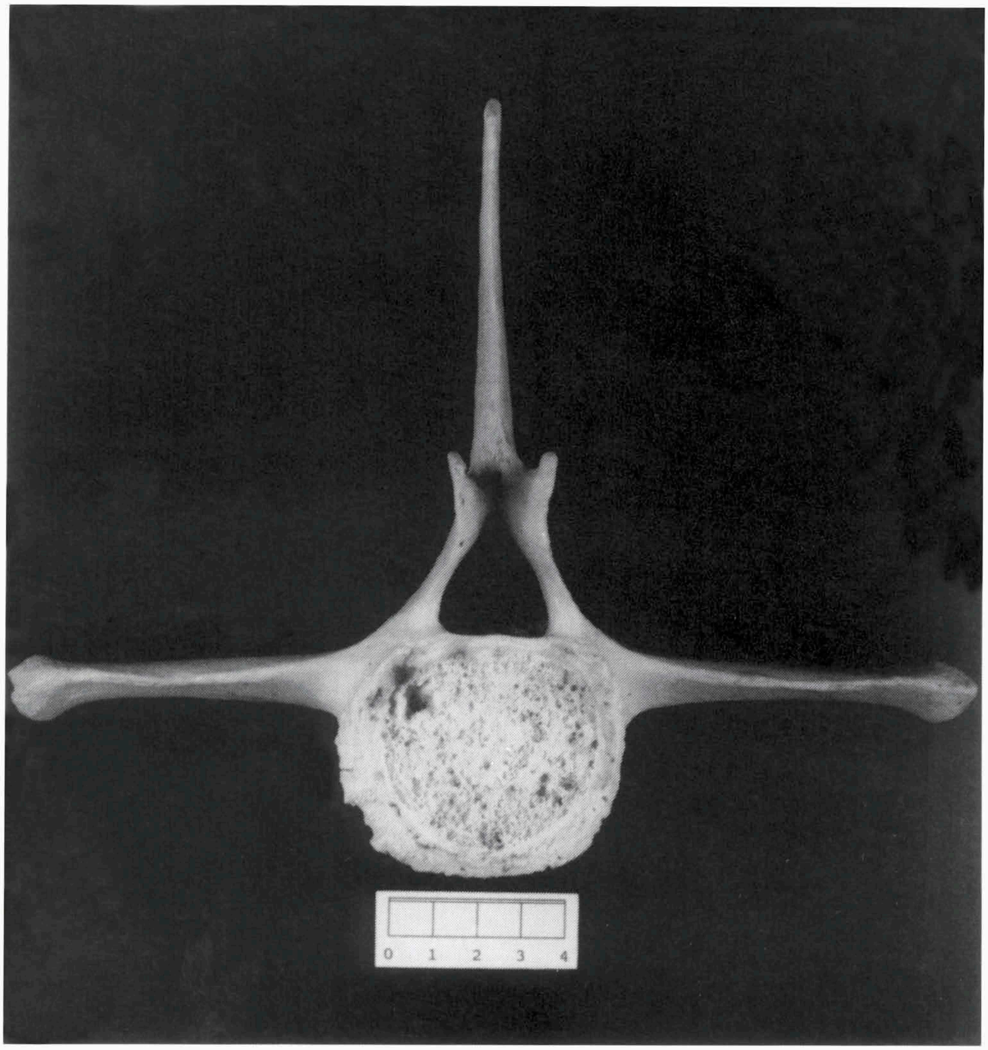

Fig. 4. *Lagenorhynchus albirostris*, thoracic vertebra with marginal osteophytes and degeneration of the bony vertebral plate, with new bone formation (adult ♀, RMNH 18067) (Mr R. 't Hart).

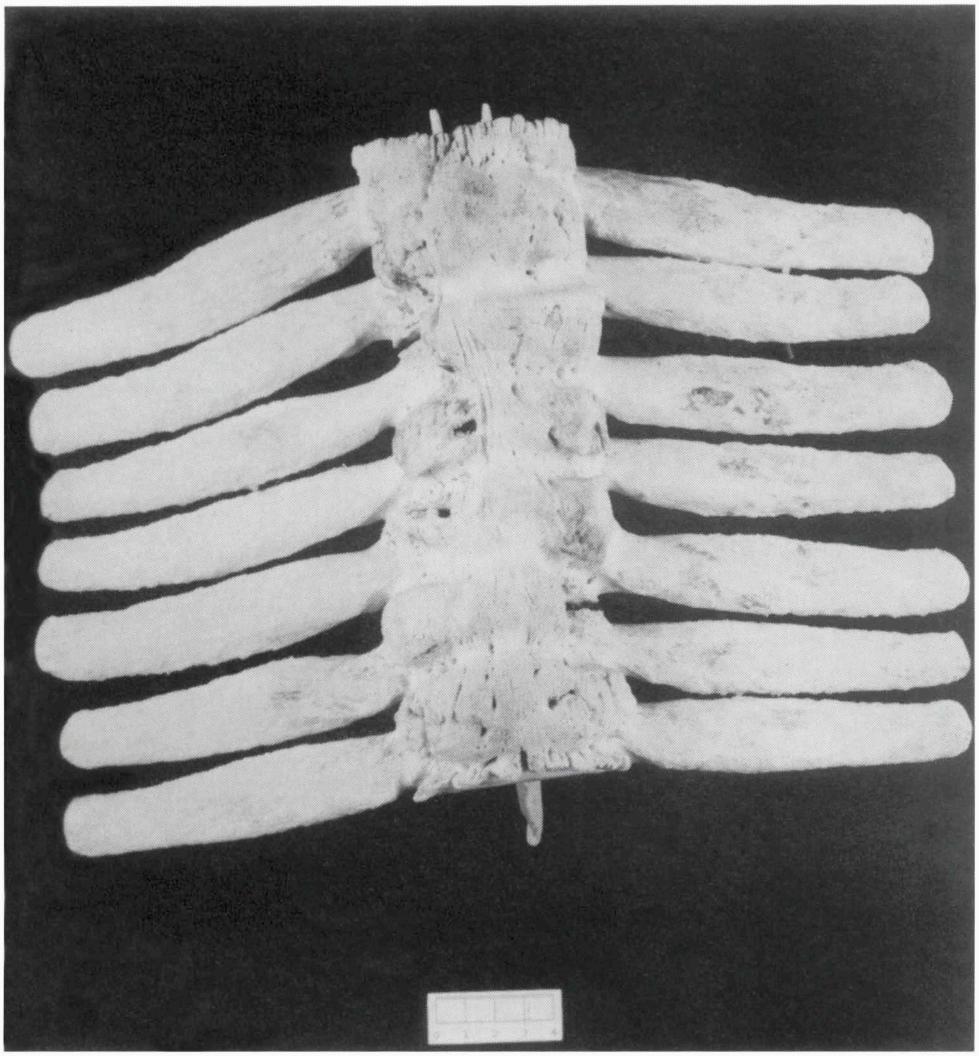

Fig. 5. *Lagenorhynchus albirostris*, ankylosis between seven lumbar vertebrae (adult ♀, RMNH 18067) (Mr R. 't Hart).

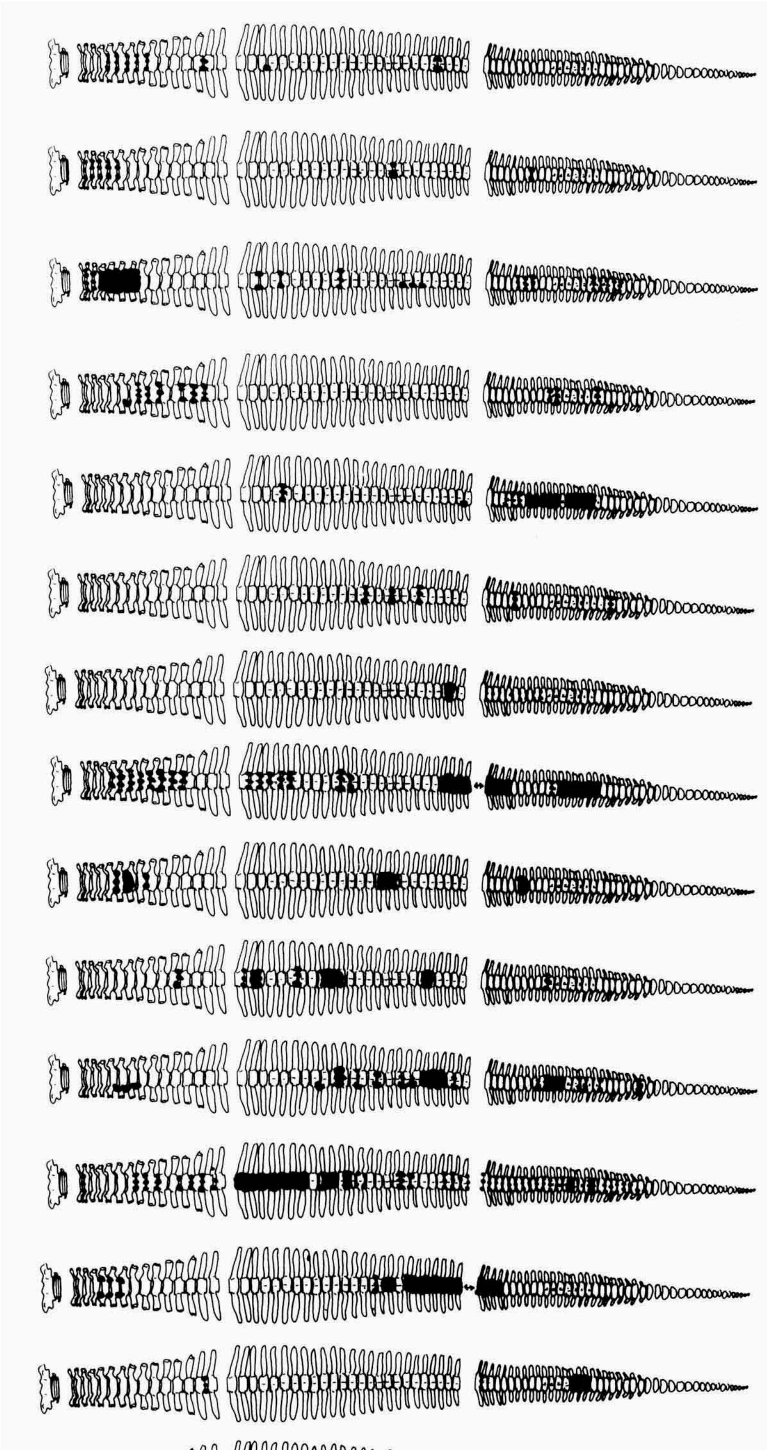

Fig. 6. *Lagenorhynchus albirostris*, schematic occurrence of spondylosis deformans in 15 vertebral columns. Black spots indicate osteophytes or lipping of osteophytes and the black regions indicate ankylosis.

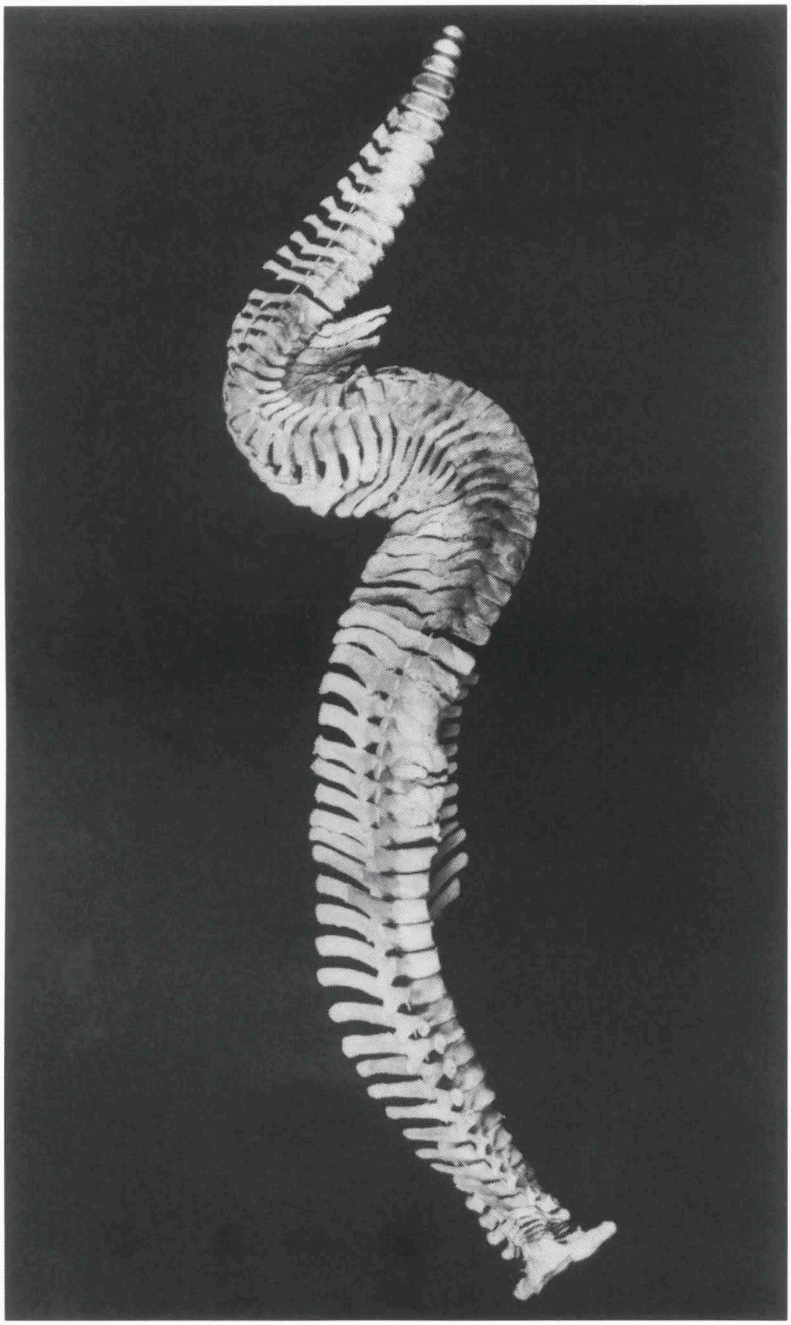

Fig. 7. *Lagenorhynchus albirostris*, pathological changes in the vertebral column of ZMA 17.232. Complete vertebral column (Mr R. 't Hart).

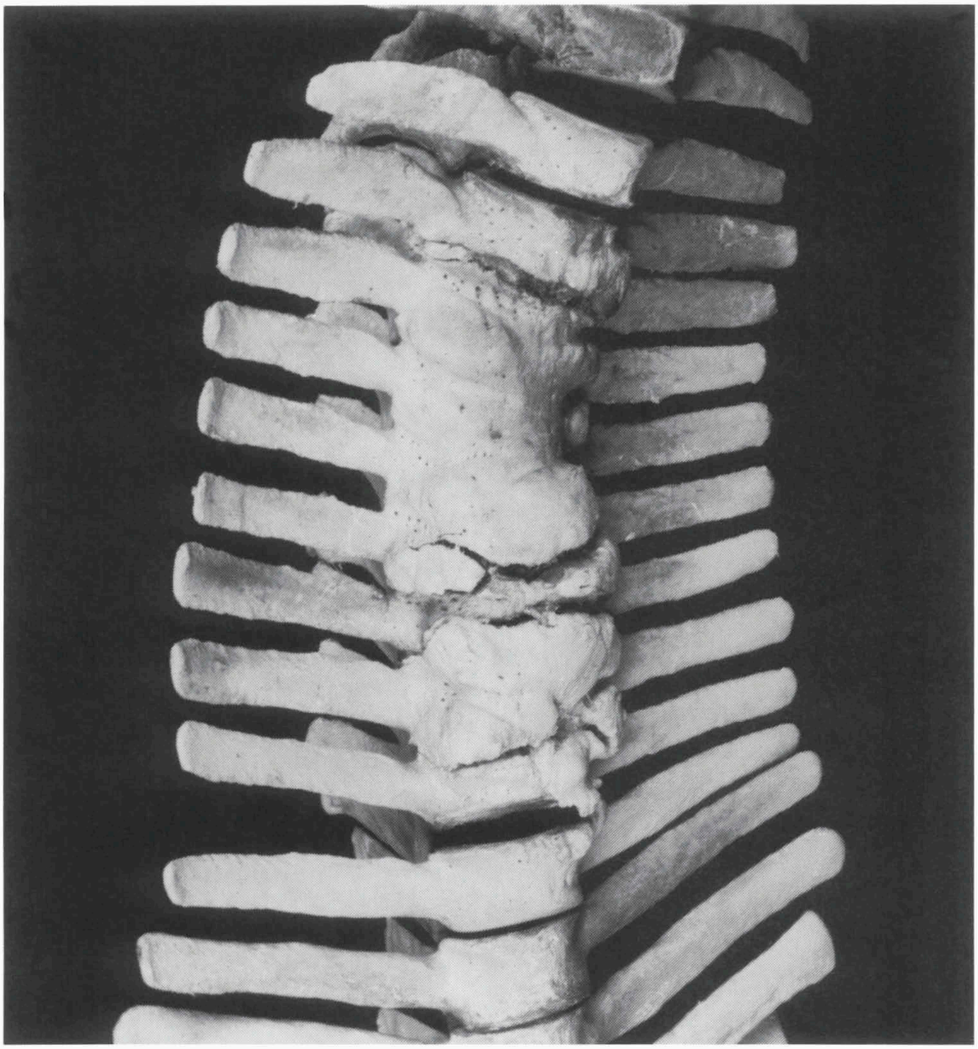

Fig. 8. *Lagenorhynchus albirostris*, pathological changes in the vertebral column of ZMA 17.232. Ankylosis and 'parrot-beaking' in the 4th to 10th lumbar vertebrae (Mr R. 't Hart).

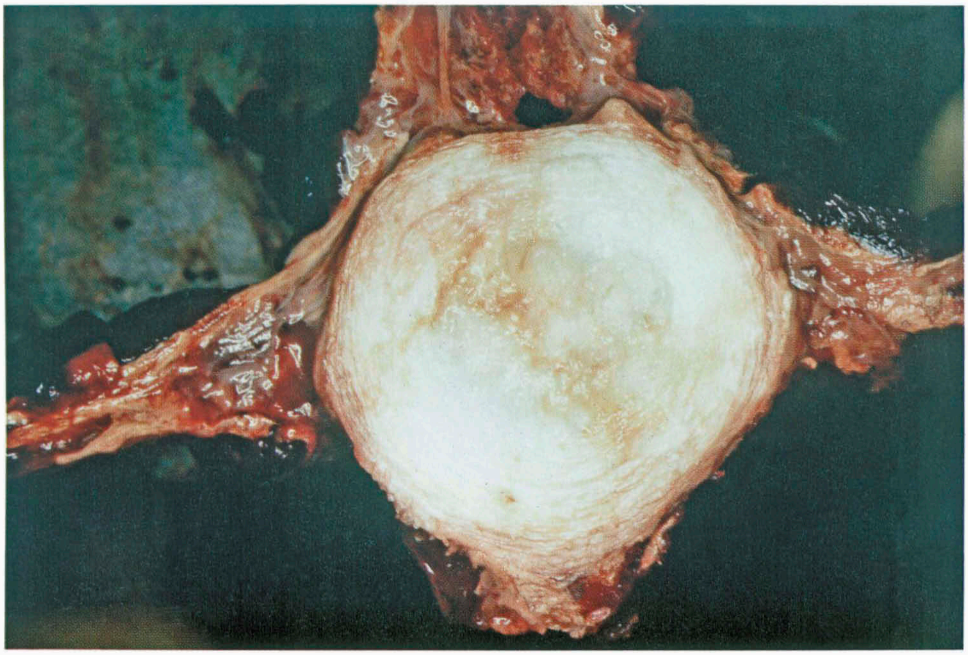

Fig. 9. *Lagenorhynchus albirostris*, normal annulus fibrosus and nucleus pulposus in the thoracic region (adult ♀, RMNH 38415) (Mr M. García Hartmann).

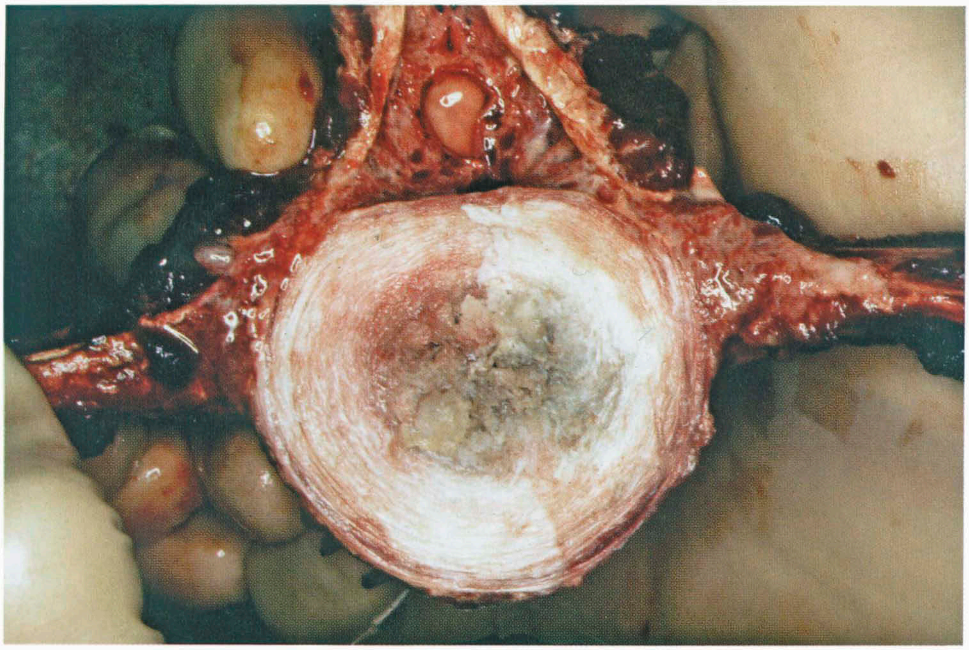

Fig. 10. *Lagenorhynchus albirostris*, necrosis of the nucleus pulposus in the lumbar region (adult ♀, RMNH 38415) (Mr M. García Hartmann).

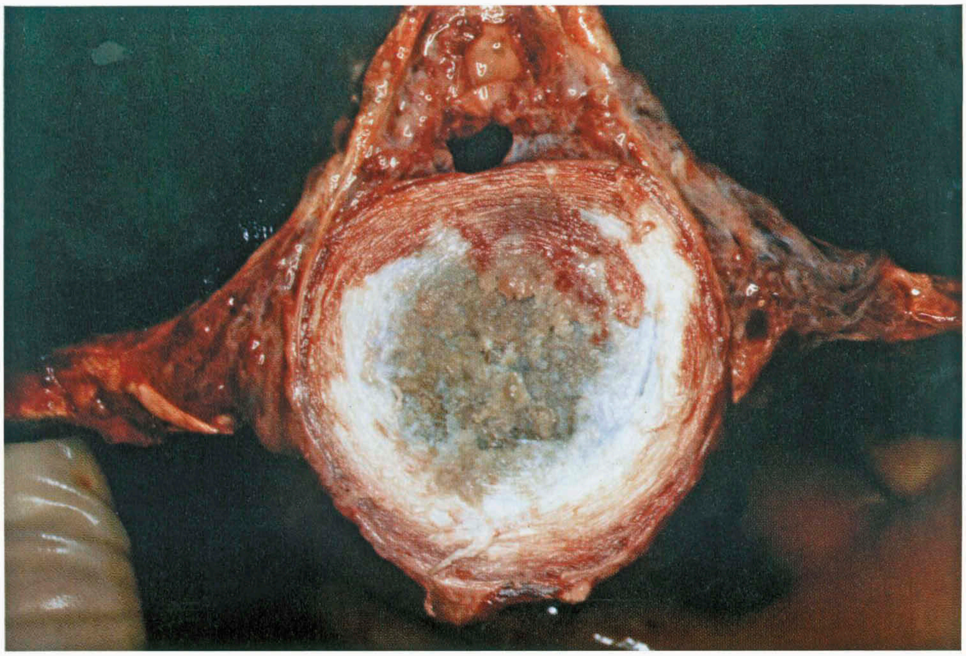

Fig. 11. *Lagenorhynchus albirostris*, necrosis of the nucleus pulposus, degeneration of the annulus fibrosus and pathological changes of the bony vertebral plate with new bone formation in the lumbar region. Also marginal osteophytes are seen (adult ♀, RMNH 38415) (Mr M. García Hartmann).

Fig. 12. *Lagenorhynchus albirostris*, pathological changes in the vertebral column of ZMA 17.232. Kyphosis between the 12th lumbar and 17th caudal vertebra (Mr R. 't Hart).

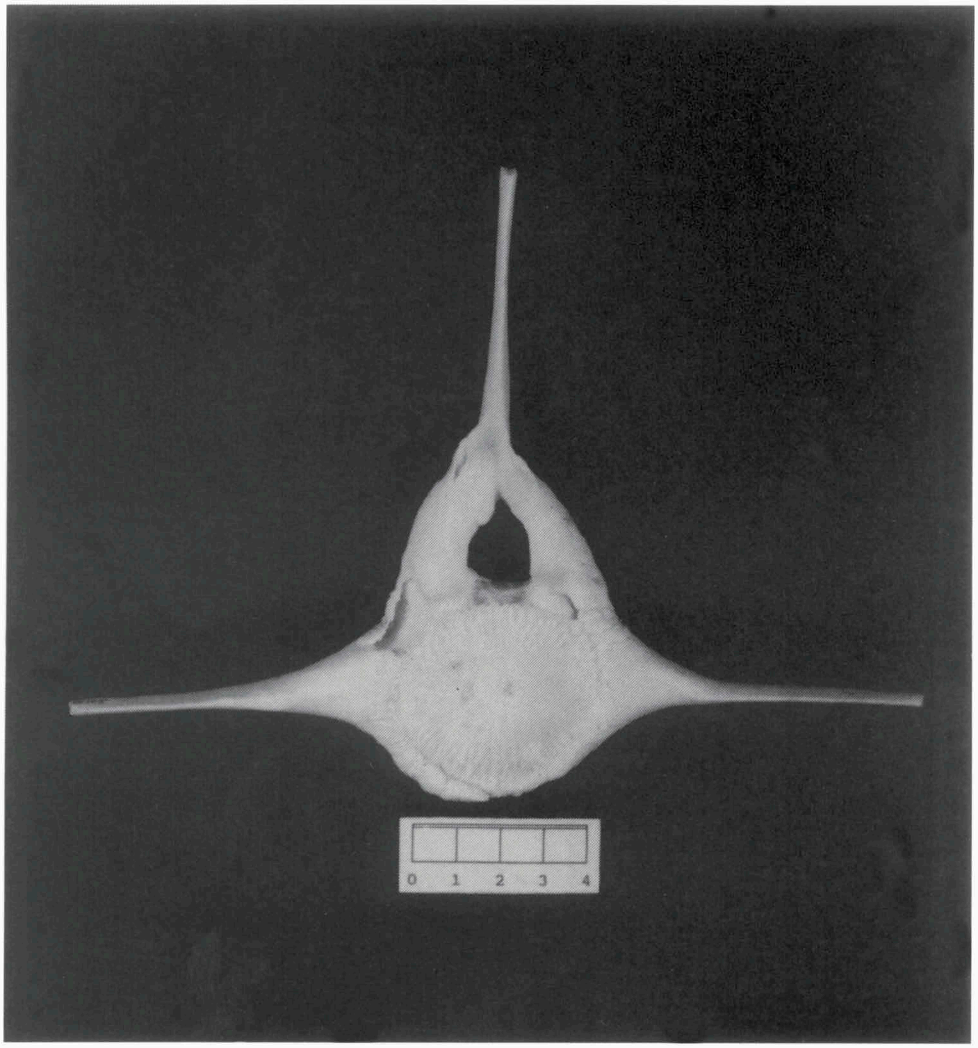

Fig. 13. *Lagenorhynchus albirostris*, lumbar vertebra of an immature ♀ (RMNH 32233). Vertebral osteomyelitis with reactive hyperostosis of the lamina (Mr R. 't Hart).

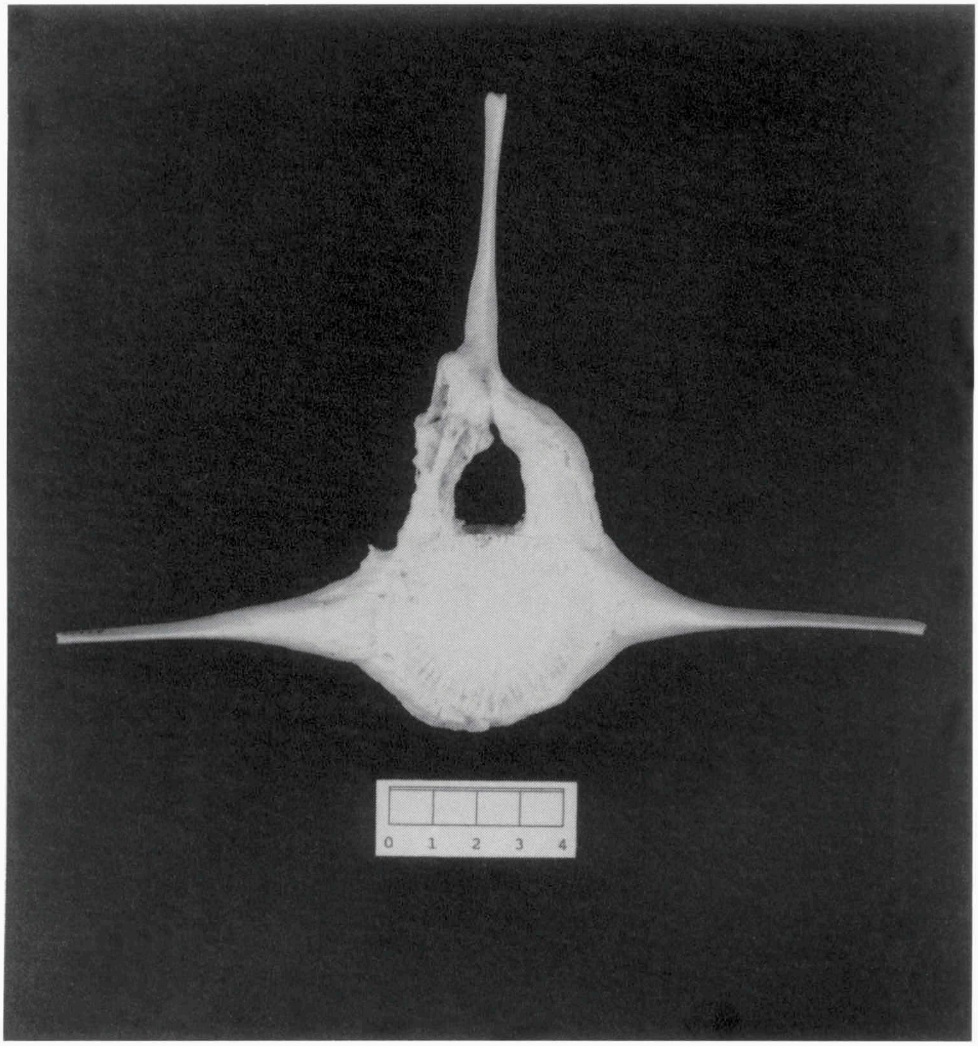

Fig. 14. *Lagenorhynchus albirostris*, lumbar vertebra of an immature ♀ (RMNH 32233). Vertebral osteomyelitis with destruction of the lamina and marginal osteophytes on the ventral side of the vertebral body (Mr R. 't Hart).