Vol. 120: 9–15, 2016
doi: 10.3354/dao03010

DISEASES OF AQUATIC ORGANISMS
Dis Aquat Org

Published June 15

Pathology in skeletons of Peale's dolphin *Lagenorhynchus australis* from southern South America

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ABSTRACT: Peale's dolphin *Lagenorhynchus australis* is frequently seen off the coast of southern South America, where it feeds among coastal kelp beds and occasionally strands. We searched for macroscopic evidence of skeletal lesions in 78 specimens of Peale's dolphin from 2 museum collections, which contain almost all of the species' skeletons known in collections worldwide. Thirty-two specimens (41%) had some type of osteological abnormalities. In 21 cases (66%), congenital deformations were the most predominant abnormality found. Acquired lesions included (1) induced trauma: abnormal curvature (n = 5 specimens) and fractures (n = 2); (2) infectious diseases: spondylo-osteomyelitis (n = 3); and (3) degenerative diseases: exostoses (n = 8) and spondylosis deformans (n = 4). It is noteworthy that all of these animals died incidentally in gillnet entanglement and were presumably healthy at the time of death. The effect that different osseous lesions may have on an animal's quality of life may depend on the area of the spine affected and the number of vertebrae involved.

KEY WORDS: Cetacean · Stranding · Congenital anomalies · Tierra del Fuego

INTRODUCTION

Peale's dolphin *Lagenorhynchus australis* is the most commonly seen cetacean off the coast of Tierra del Fuego, where it feeds in coastal waters and occasionally strands. *L. australis* is mainly a coastal species common in the Southern Hemisphere from about 38° S in the SW South Atlantic and 33° S in the SE South Pacific, to south of Cape Horn (Goodall et al. 1997) and Namuncurá-Banco Burdwood Marine Protected Area (about 57° S). This species seems to prefer the cold waters of the southern part of the continent.

Osseous lesions found in cetaceans commonly affect the vertebral body, the spinous processes, the transversal processes, zygapophyseal joints, and the ribs. To a lesser extent, lesions may be observed on the skull, scapula, sternum, and bones of the flippers (de Smet 1977, Pascual et al. 2000, Montes et al. 2004, Kompanje & Van Leeuwen 2009, Arbelo et al. 2013). Osseous lesions of the vertebral column and associated structures can be produced by discarthrosis and zygarthrosis (spondylarthrosis or spondylosis deformans) (Peterson 1984, Kompanje 1995a,b, 1999, Kompanje & Garcia Hartmann 2001, Galatius et al. 2009), infectious spondylo (discitis) (Kompanje 1995b, 1999, Sweeny et al. 2005, Félix et al. 2007), spondyloarthritis (spondyloarthropathy) (Kompanje 1999, Kompanje & Garcia Hartmann 2001, Rothschild et al. 2005), and intraspongious disc herniation (Schmorl's nodes) (Kompanje & Garcia Hartmann 2001). Spondylosis deformans occurs only in adult animals and is

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restricted to the vertebral body and adjacent processes. During the final stage of this disease, ankylosis occurs with destruction of the epiphysis (Kompanje 1995a). Spondylosis deformans occurs due to degeneration of the annulus fibrosus of the intervertebral disc, which leads to a secondary bone growth (Galatius et al. 2009).

Vertebral infections are mostly considered to be of 1 of 3 origins: hematogenous, direct local wound, or local infection produced by bacteria, viruses, fungi, or protozoa (Turnbull & Cowan 1999) either by a direct penetration through a wound, blood stream infection, or infections in adjacent organs (Kompanje 1995b, 1999, Turnbull & Cowan 1999). Post mortem examinations of these animals rarely occur within a few hours or days of stranding, when they are still fresh, making the diagnosis of cases of infectious spondylo (discitis) a difficult task (Kompanje 1999). Even more challenging is to identify the etiologic agent in cases limited to skeletal remains, given that most of the skeletal material in collections has been previously cleaned, which makes extraction of pathogen DNA difficult.

Congenital anomalies developed during ontogenesis are frequent and are similar to those found in humans and other mammals (Ortner & Putschar 1985, Williams et al. 1989, Barnes 1994, Hall 2005). Exostoses have also been reported where bone growth occurs over the bone surface, especially where ligaments and tendons are inserted (de Smet 1977, Montes et al. 2004).

Bony lesions in cetaceans are well documented mainly for some Northern Hemisphere species (Kompanje 1995a,b, Galatius et al. 2009), but limited information is available about bony lesions in cetaceans of the Southern Hemisphere, including Peale's dolphin (Fragoso 2001, Ramos et al. 2001, Montes et al. 2004, Van Bressem et al. 2006, 2007, Laeta et al. 2010a,b, Fettuccia et al. 2013). The Museo Acatushún holds the world's largest collection of Peale's dolphin, and the aim of this work is to describe and quantify the osseous lesions found in this species.

MATERIALS AND METHODS

We examined 78 specimens of Peale's dolphin (Table 1), of which 18 were complete, with complete spines (Type A, sensu Goodall); 5 were incomplete, lacking some vertebrae (Type B); and 46 were groups of 3 to 60 vertebrae (Type E). Seventy of the examined specimens belong to the Goodall collection (RNP) and are deposited in the Museo Acatushún de Aves y Mamíferos Australes (AMMA), located at Estancia Harberton, Tierra del Fuego, Argentina (Goodall 1978, Goodall et al. 1997). Specimens were collected from 1974 to present during beach surveys along the coast of northeastern Tierra del Fuego, from Cabo Espíritu Santo, 52° 40′ S, to Cabo San Pablo, 54° 23′ S (Goodall 1978, Goodall et al. 1994, 2008; Fig. 1). The remaining 8 skeletons were collected for scientific purposes in the Chilean channels between Isla Chiloé and Cape Horn by the K. S. Norris expedition in 1968 (K. S. Norris unpubl.) and are deposited in the Smithsonian Museum, Washington, DC, USA. Stranding date and location, condition and type of specimen, and when possible sex, age, and physical maturity are reported in Table 1.

For this work, only postcranial lesions were reviewed. The vertebrae and ribs of each specimen were examined macroscopically. The identification of the abnormalities was performed by observation of different patterns of osseous growth that are characteristic for different diseases in cetaceans. The skele-

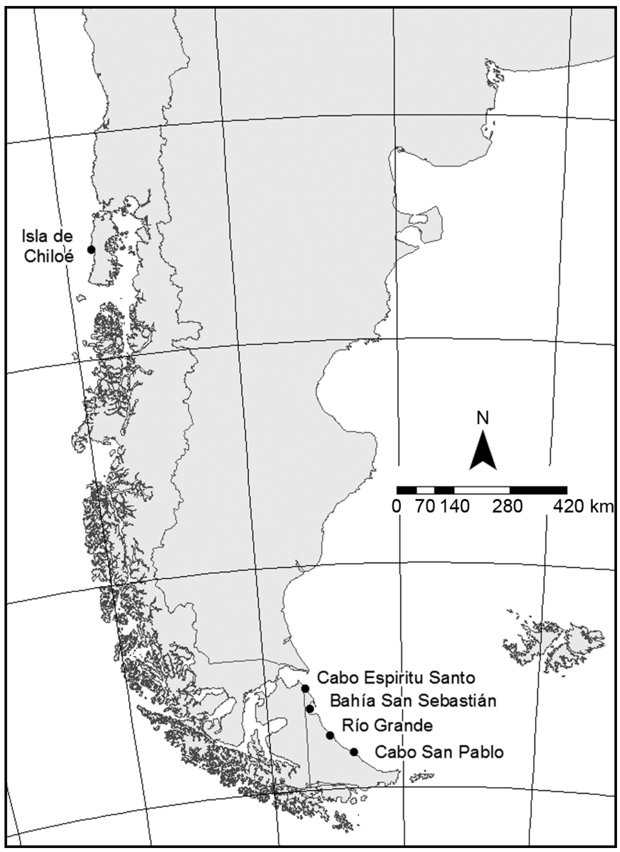

Fig. 1. Sites (•) where most of the investigated *Lagenorhynchus australis* stranded in Tierra del Fuego Island, Argentina, and Isla de Chiloé, Chile

Table 1. Records of *Lagenorhynchus australis* specimens from southern South America, collected between 1974 and 2014, examined in this study, with corresponding locality, sex, age (following Boy et al. 2011), the lesion found, and the region of the spinal column where the lesion was located. Specimen types were defined as follows: A: complete, with complete spines; B: incomplete, lacking some vertebrae; and E: groups of 3 to 60 vertebrae. –: not determined

Collection no.	Sex	Age (yr)	Specimen type	Locality	Lesion(s)	Affected area(s)
RNP0 97	–	–	E	Península Páramo	Exostosis	Caudal
RNP 179	–	–	E	Estancia Moat	Congenital	Cervical
RNP 269	–	1.9	A	Bahía San Sebastián	Congenital	Cervical
RNP 427	–	–	E	Cabo Peñas	Congenital	Cervical
RNP 554	–	–	E	Río Cullen	Spondylosis deformans	Thoracic
RNP 649	F	4	A	Península Páramo	Congenital	Cervical
RNP 713	–	–	E	Porvenir, Faro Pta. Palo (Chile)	Exostosis	Thoracic, Lumbar
RNP 716	F	3	A	Bahía Slogget	Congenital Exostosis	Cervical Lumbar, Caudal
RNP 717	F	1.7	A	Bahía Slogget	Congenital	Cervical
RNP 718	F	3	A	Bahía Slogget	Congenital	Cervical
RNP 719	F	13	A	Bahía Slogget	Congenital	Cervical
RNP 720	F	3.8	A	Bahía Slogget	Congenital	Cervical
RNP 753	F	11	A	Bahía San Sebastián	Congenital Exostosis	Cervical, Thoracic
RNP 761	–	0.8	A	Bahía San Sebastián	Congenital	Cervical
RNP 777	–	–	E	Estancia Sara, Puesto	Exostosis	Thoracic
RNP 836	–	7	A	Bahía San Sebastián	Congenital	Cervical
RNP 889	–	–	E	Río Grande, La Misión	Congenital	Cervical
RNP 918	–	–	E	Bahía Valentín	Spondylosis deformans	Thoracic
RNP 1149	–	–	E	Estancia Sara, Puesto	Exostosis Spondylosis deformans	Thoracic Lumbar
RNP 1164	F	1.9	A	Rio Lainez	Congenital	Cervical
RNP 1184	–	–	E	ES, Puesto	Congenital	Cervical
RNP 1475	F	7	B	Cabo Espíritu Canto	Congenital	Cervical, Lumbar
RNP 1476	M	2	B	Cabo Espíritu Canto	Congenital	Cervical, Lumbar
RNP 1760	M	5	A	Península Páramo	Infection	Lumbar
RNP 1855	–	5	A	Península Páramo	Congenital	Cervical
RNP 2024	F	4	A	Estancia Sara	Congenital	Cervical
RNP 2577	M	0.8	A	Bahía San Sebastián	Congenital	Cervical
RNP 2796	–	–	A	Bahía San Sebastián	Infection Spondylosis deformans Exostosis	Cervical, Thoracic, Caudal Thoracic Caudal
RNP 2805	–	–	B	Punta Sinai	Exostosis	Lumbar
USNM 395345	F			Isla Coloca, Chile	Congenital	Lumbar

ton of Peale's dolphin is typically composed of 66 vertebrae: 7 cervical (C), 13 thoracic (Th), 15 lumbar (L), and 31 caudal (Ca) (Brownell et al. 1999). After the abnormal skeletons had been identified, they were classified into types of specimens and types of lesions, and if possible, their probable causes were determined (Table 2).

RESULTS

Thirty-two of the 78 (41%) specimens had osseous abnormalities on the vertebrae and ribs. The most frequent osseous lesion were congenital anomalies observed in 21 specimens (66% of the specimens with abnormalities), and among these, the most frequent (14 specimens) occurred in cervical vertebrae C5, C6, and C7 (though most predominantly on C7), which presented cervical ribs (Fig. 2).

Table 2. Skeletal lesions found in 32 of 78 examined Peale's dolphins *Lagenorhynchus australis* from southern South America, collected between 1974 and 2014. Several individuals presented more than 1 type of lesion. N: number of individuals; Ind. (%): percentage of affected individuals

Lesion	N	Ind. (%)
Spondylosis deformans	4	13
Congenital anomalies	21	66
Infection	3	9
Trauma induced	5	16
Periostitis	8	25

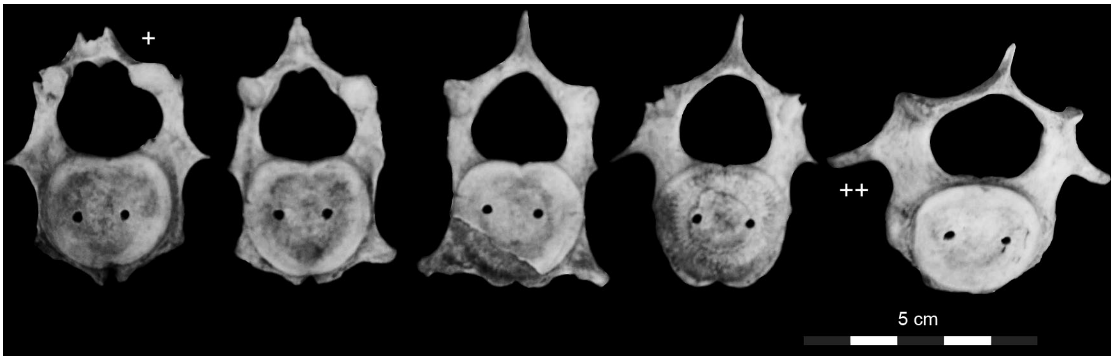

Fig. 2. Cervical vertebrae (C3 to C7) of *Lagenorhynchus australis* with congenital anomalies. Spine bifida occulta in vertebra C3 (+). In C7, the transverse processes are longer than normal (++)

Other congenital anomalies found in *Lagenorhynchus australis* were an unfused neural arch, fused neural spinous processes, and spina bifida occulta. The unfused neural arch was found in 4 dolphins; 3 of these affected the C3 and the C7 vertebrae. The spinous processes of 2 lumbar vertebrae were fused in 4 specimens; 2 of these were found together on the beach, with the same pattern: the upper part of the neural spines of lumbar vertebrae L10 and L11 were fused together (Fig. 3). The specimens also had fused spinous processes of 2 adjacent lumbar vertebrae, but it was not possible to determine their location because the vertebrae of the lumbar region were not complete. In all cases, the fusion was smooth, showing none of the typical signs of osteomyelitis or any other condition that may have caused the fusion.

The acquired or trauma-induced lesions observed were fractures or abnormal curvatures, such as the curving of spiny or transverse processes of the vertebrae modifying the column axis. We observed 5 (16%) specimens with abnormal curvature of the spinous processes of the thoracic vertebrae, and in all cases, this curvature involved groups of 2 to 6 vertebrae. Regarding lesions related to infections, 3 specimens (9%) had lesions compatible with spondylo-osteomyelitis (Fig. 4). In 2 of these, the infections were located on only 2 adjacent vertebrae. In the third specimen, the degree of infection was severe; the cervical vertebrae exhibited ventral marginal osteophytes with growth, and on the articular surface of the atlas, we observed marked erosion and fistula formation. Several pairs of thoracic vertebrae were fused through the formation of excessive and disorganized ankylosis, and a fistula caused by the drainage of pus was visible. Vertebrae Th2 and Th3 were fused by ankylosis, Th3 had severely eroded epiphysis, Th4 and Th5 were fused by the formation of exuberant marginal osteophytes, Th6 showed erosion of the epiphysis and formation of marginal ventral osteophytes, Th7 showed marginal osteophytes, and Th8 showed the formation of ventral marginal osteophytes with insertion in Th7.

Eight specimens (25%) were found with lesions caused by exostoses in the spinous and transverse processes of thoracic, lumbar, and caudal vertebrae. In 3 of them, exostosis was found in the transverse processes of 2 thoracic vertebrae and in the spinous processes of Th1 to Th8. Exostoses were observed in the transverse processes of lumbar vertebrae of 4 animals, and finally in the transverse processes of the caudal vertebrae of 1 animal.

Four specimens (13%) showed evidence of spondylosis deformans. This degenerative disease was found in varying degrees of severity. Two of the specimens showed the first degree of severity, i.e. erosion of the epiphysis and marginal osteophytes. The other 2 animals had the most advanced signs of

Fig. 3. Abnormal congenital fusion of the spinous processes of *Lagenorhynchus australis*. This anomaly is repeated in 4 specimens; all fusions occurred in the lumbar region but varied in their position in the vertebra. Left: caudal end; right: cranial end

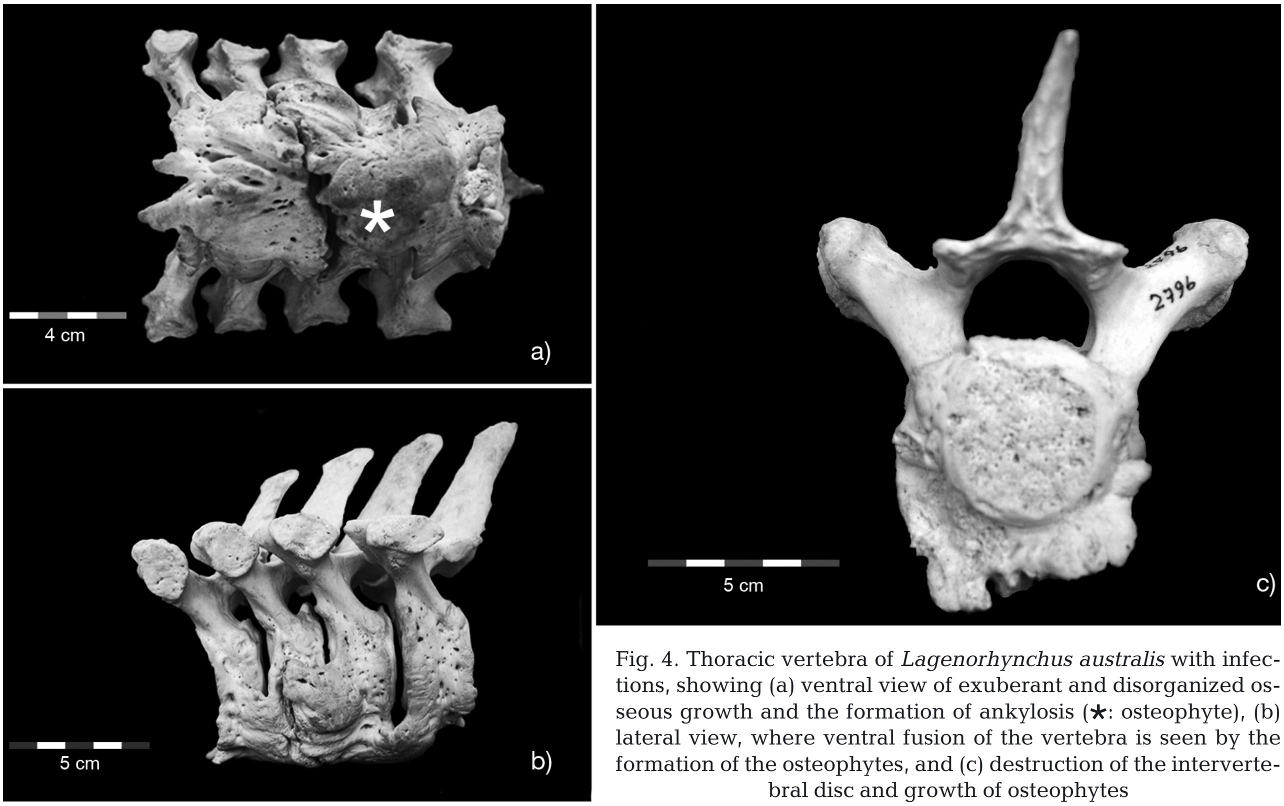

Fig. 4. Thoracic vertebra of *Lagenorhynchus australis* with infections, showing (a) ventral view of exuberant and disorganized osseous growth and the formation of ankylosis (*: osteophyte), (b) lateral view, where ventral fusion of the vertebra is seen by the formation of the osteophytes, and (c) destruction of the intervertebral disc and growth of osteophytes

the disease. One of them presented the 'parrot beak' (sensu Kompanje 1996) and advanced osteophytes growing in the thoracic vertebra Th4. The other specimen showed only 3 vertebrae fused together by formation of smooth ankylosis, representing the final stage of the disease.

DISCUSSION

The *Lagenorhynchus australis* specimens analyzed here represent almost all of the skeletons available in worldwide collections, and we found that 41% of the specimens had diseases reported for other species such as bottlenosed dolphins *Tursiops truncatus,* white-beaked dolphins *L. albirostris*, and Commerson's dolphins *Cephalorhynchus commersonii commersonii*, among others. Skeletal abnormalities are well documented in many species of cetaceans from around the world, including both dolphins and whales (e.g. de Smet 1977, Peterson 1984, Alexander et al. 1989, Kompanje 1999, Fragoso 2001, Montes et al. 2004, Van Bressem et al. 2006, 2007, Félix et al. 2007, Laeta et al. 2010a,b). The great majority of the research on cetacean skeletal abnormalities has been conducted on species from the Northern Hemisphere (Peterson 1984, Kinze 1986, Alexander et al. 1989, Kompanje 1996, 1999, Van Bressem et al. 2006, Félix et al. 2007, Galatius et al. 2009, Fettuccia et al. 2013) and some on species of northern South America (Ramos et al. 2001, Montes et al. 2004, Van Bressem et al. 2007, Laeta et al. 2010a,b).

The most frequent lesions in *L. australis* were congenital anomalies, which were found in 66% of the specimens with bone pathologies, and with a higher frequency than those found in the other common dolphin in Tierra del Fuego, viz. Commerson's dolphin (San Martín 2014). The most frequent congenital anomalies in cetaceans are the unfused neural arch and cervical rib, e.g. in Guiana dolphins *Sotalia guianensis* (Laeta et al. 2010b) and *C. commersonii commersonii* (San Martín 2014). In *C. commersonii*, the cervical rib was only found in C7. In *L. australis*, the cervical rib was found in C6 and C7: the most frequent lesions found were the presence of cervical ribs (67%), followed by an unfused neural arch (19%). The proportion of individuals with unfused neural arches, as well as the number of vertebrae per individual involved, was lower in *L. australis* than in other species. For example, San Martín (2014) found unfused neural arches in *C. commersonii commersonii,* not only in C6 and C7, but also in C3, Th1, and Th2. Both congenital anomalies are mainly related to nutritional deficiencies in the B9 vitamin complex

(Minns 1996, Fleming & Copp 1998, Jablonski & Chaplin 2000), and in the case of the marine environment, these nutritional deficiencies may be related to environmental changes (Jablonski & Chaplin 2000). The observation of older individuals with congenital abnormalities suggests that this kind of anomaly does not affect the survival of individuals.

Exostoses were the second most common lesion found in the Peale's dolphin skeletons. The few reports that have described this disease in cetaceans referred to cases of exostosis is in the skull (de Smet 1977), in the vertebral body (Nathan 1962, Kompanje 1999), at the joint of the humerus and scapula, and in the ribs (Groch et al. 2012).

The remaining lesions present in Peale's dolphin were found in low numbers, affecting only a few specimens. Spondylosis deformans and joint osteoarthritis are lesions related to aging and wear of the joints. Spondylosis deformans is a disease well documented in other species of cetaceans such as *L. albirostris*, *S. guianensis*, Atlantic spotted dolphin *Stenella frontalis*, humpback whales *Megaptera novaeangliae*, and beluga (or white) whales *Delphinapterus leucas*, among others (Kompanje 1995a, 1996, 1999, Furtado & Simões-Lopes 1999, Galatius et al. 2009, Groch et al. 2012). Spondylosis deformans causes the loss of flexibility due to the formation of large osteophytes that immediately cause rigidity of the vertebral bodies. Although in *L. australis* this disease was observed only in the initial stages (first degree of severity), the consequence, depending on the area of the vertebral column that is affected, is decreased mobility of the individual.

Two individuals presented osteomyelitis. One of these cases was a point infection that affected only 2 vertebrae, and the other specimen showed a more severe infection that affected several thoracic vertebrae. In both cases, it was not possible to determine the cause, given that we had only skeletons and lacked samples of soft tissues for examination of pathogens. Depending on the degree of infection and the affected regions, osteomyelitis would lead to death of the individual. Post mortem examination of animals stranded in Tierra del Fuego can rarely be performed within a few hours or days after the stranding occurs. Furthermore, and depending on the condition of the carcass (e.g. freshly dead, moderately decomposed), it can be difficult to collect the samples required for the proper diagnosis of various infectious diseases (Kompanje 1999). Most strandings that occur on the coast of Tierra del Fuego are the result of bycatch in gillnets, suggesting that in our specimens, death was not caused by infections.

Acknowledgements. We are grateful to the Committee for Research and Exploration of the National Geographic Society for grants which have funded our field research. We thank Total Austral SA of Argentina and the Fondation Total D'Entreprise of France for granting fellowships to S.V.M. to study cetacean pathology. We also thank the many volunteers who contributed to the collection and cleaning of specimens over the years. Estancias Harberton, Moat, Viamonte, San Martín, and Cullen assisted the Goodall team during the expeditions. J. G. Mead kindly provided access to the specimens under his care at USNM. We would also like to thank E. J. O. Kompanje for providing valuable literature, for sharing his expertise on cetacean pathology, and for reviewing and improving this manuscript. Thanks also E. Gimeno, M. Van Bressem, and A. C. M. Schiavini for reviewing drafts and offering valuable advice. Finally, we thank Florencia Sangermano and Romina Pousa for the revision of the language.

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Editorial responsibility: Sven Klimpel, Frankfurt, Germany

Submitted: September 7, 2015; Accepted: April 29, 2016
Proofs received from author(s): May 19, 2016