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## Case Report

# Rare Cranial Osteopathy in a Northern Bottlenose Whale (*Hyperoodon ampullatus*) Stranded in Rhode Island, Northwest Atlantic, in the 19th Century

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**Abstract:** Few reports exist on the pathologies of the northern bottlenose whale (*Hyperoodon ampullatus*) and other Ziphiidae. We here describe a large exostosis in the right pterygoid bone of adult female *H. ampullatus* ANSP-3004 that stranded on the US Atlantic coast in 1867. Images of the skull and 14 cranial measurements were examined and compared with two 'normal' adult female *H. ampullatus* specimens. Surface scans of ANSP-3004 were made with a Faro Design Arm 1.0 scanner at 75µm resolution. The form, structure and width (15.9 cm) of the right pterygoid were found to be abnormal. Its distal extremity was curved in labial direction while its proximal extremity was deformed by a large, bulbous exostosis of 14.3 x 12.5 cm that partially obstructed the right nasal passage. Lytic lesions in the posterior end of the exostosis exposed deep resorption lacunae. The left pterygoid was thin (3.4 cm) and laterally displaced. No diagnosis was possible for lack of histological examination but the osteopathy was consistent with osteoma, a benign bone tumor commonly seen on the jaws and nasal sinuses of bovines, phylogenetical relatives of Cetacea. The partial nasal passage obstruction may have affected respiration to some degree, but since the female was lactating, general fitness appeared stable.

**Keywords:** pterygoid malformation; exostosis; osteoma; beaked whales; North Atlantic; bone disease

Northern bottlenose whales *Hyperoodon ampullatus* (Forster 1770) are large-sized beaked whales (up to 9.7m) that inhabit deep, subarctic to temperate waters of the North Atlantic Ocean (south to ca. 37 °N) where they primarily feed on squid species of the genus *Gonatus* (Whitehead et al. 2003, 2021, Moors-Murphy 2018). Bottlenose whales were heavily hunted throughout their range in the period 1880 to 1920 and, then again, in 1937 to 1973, causing an estimated 40% reduction of their population (Taylor et al. 2008, Whitehead & Hooker 2012). Though precise estimations are not available, the entire North Atlantic population is estimated to number at least 20,000 individuals. Currently, anthropogenic sound from military mid-frequency sonar and seismic surveys as well as bycatch in fisheries are the main threats for this species (Whitehead & Hooker 2012). As a result of the historical depletion, the uncertainty of abundance estimates, and the exposition to harmful anthropogenic factors, northern bottlenose whales have been listed as 'near threatened' on the IUCN Red List of Threatened Species (Whitehead et al. 2021).

There are only few reports on the pathologies of *H. ampullatus*, even in stranded individuals. Dagleish et al. (2007) described severe mycotic encephalitis caused by the fungus *Aspergillus fumigatus* in a juvenile male *H. ampullatus* stranded in North Kessock, Scotland, in October 2006. Tattoo skin disease, a cetacean poxvirus infection, was also observed in this individual (Dagleish et al. 2008) as well as in a juvenile female that died in the Thames River in 2006 (Van Bresse et al. 2009). Tomilin (1967) reported that the 'upper parts of the epidermis of *H. ampullatus* are sometimes affected by a pathological process of mycotic nature, resulting in the appearance of large white patches on the skin'. Feyrer et al. (2021) described anthropogenic marks, including probable entanglement and propeller-vessel strike scars, in 6.6% of the Endangered Scotian Shelf population (Nova Scotia)

photographed from 1988 to 2019. The skeleton of a young northern bottlenose whale from the Shetland Islands, curated at the Royal Belgian Institute of Natural Sciences at Brussels (RBINS), shows exostosis of the spiny processes of the caudal vertebrae. Another skeleton, at Naturalis Biodiversity Center, Leiden, is reported to have a 'bony growth on the rib' (Slijper 1938, Tomilin 1967). Slijper (1938), possibly referring to the RBINS specimen, also mentioned spondylitis deformans in this species, while Kompanje (1999) reported discarthrosis and zygarthrosis without further details. Knowledge of osteopathology in southern bottlenose whales *Hyperoodon planifrons* Flower, 1882 is even more restricted (Barcellos 1977). In this context, it is important to promote studies of pathologies in beaked whales as to better understand the natural factors that may negatively impact their conservation.

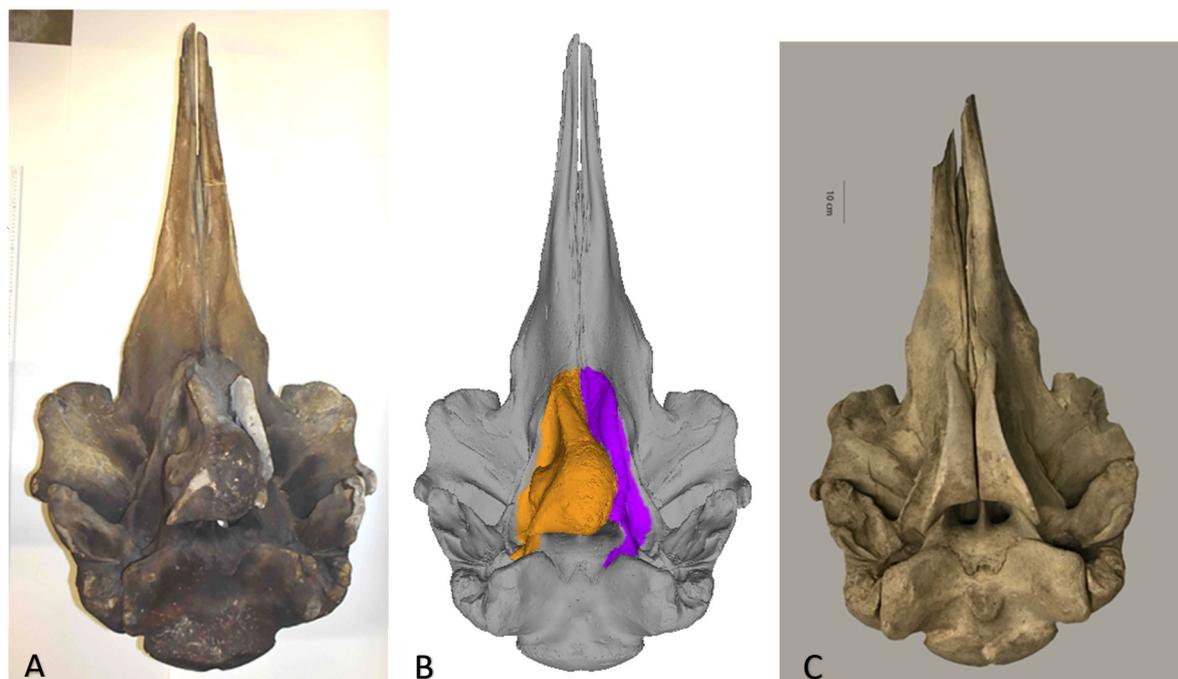
During a revision of cetacean specimens kept at the Academy of Natural Sciences of the Drexel University of Philadelphia, one of us (JA) observed a large, bulbous exostosis in the right pterygoid of an adult female *H. ampullatus* (specimen ANSP-3004) that had washed ashore on the US Atlantic coast in the 19th century. Here, we describe the case, which represents the first record of this type of pathology in ziphiids.

The 823 cm female *H. ampullatus* stranded with her calf on the shore of Narragansett Bay near Tiverton, Newport County, Rhode Island, USA, in February 1867, after being hunted and probably harpooned, based on images associated with the description (Cope 1869, Mitchell & Kosicki 1975). Cope (1869) provided the following information on the adult specimen '*Its most striking feature is the relatively longer and more slender beak, and less elevated and prominent front. Thus, in the Newport specimen, it is one-twelfth of the [body] length, or 2 1/4 feet: equal three-fourths the distance between the eye and the spout hole. The prominent swollen front is in the Newport whale. It is considerably compressed and the eye is placed in a strong longitudinal prominence on each side of the head*'. Cope (1869) further mentioned that the 'muzzle' [rostrum] of the female was longer than represented for European specimens, but this has not been confirmed. The skull was collected and donated to the museum where it was entered as ANSP-3004, two years after collection, i.e., in 1869.

Images of the ANSP-3004 skull were examined by the authors and compared to 'normal' female *H. ampullatus* specimens kept at the Naturalis Biodiversity Center, Leiden, Netherlands (courtesy P. Kamminga), at the Museum of Comparative Zoology Mammalogy, Harvard University (MCZ; courtesy M. Omura) and the Royal Belgian Institute of Natural Sciences (RBINS; courtesy O. Lambert). Fourteen cranial measurements were taken (Table 1) and compared with unpublished measurements for two other adult, female specimens: MCZ- 25362, stranded in Beverly Farms, Massachusetts, in October 1923, and RBINS-1503, stranded in Zeeland, The Netherlands, in September 1840. Craniometrics were taken by different persons, so inter-observer variability may be significant. Surface scans of ANSP-3004 were made with a Faro Design Arm 1.0 scanner at 75µm resolution. Due to the size of the specimen, several scans were realized and stitched together using the 3D Systems Geomagic 2017 software to make a single surface model.

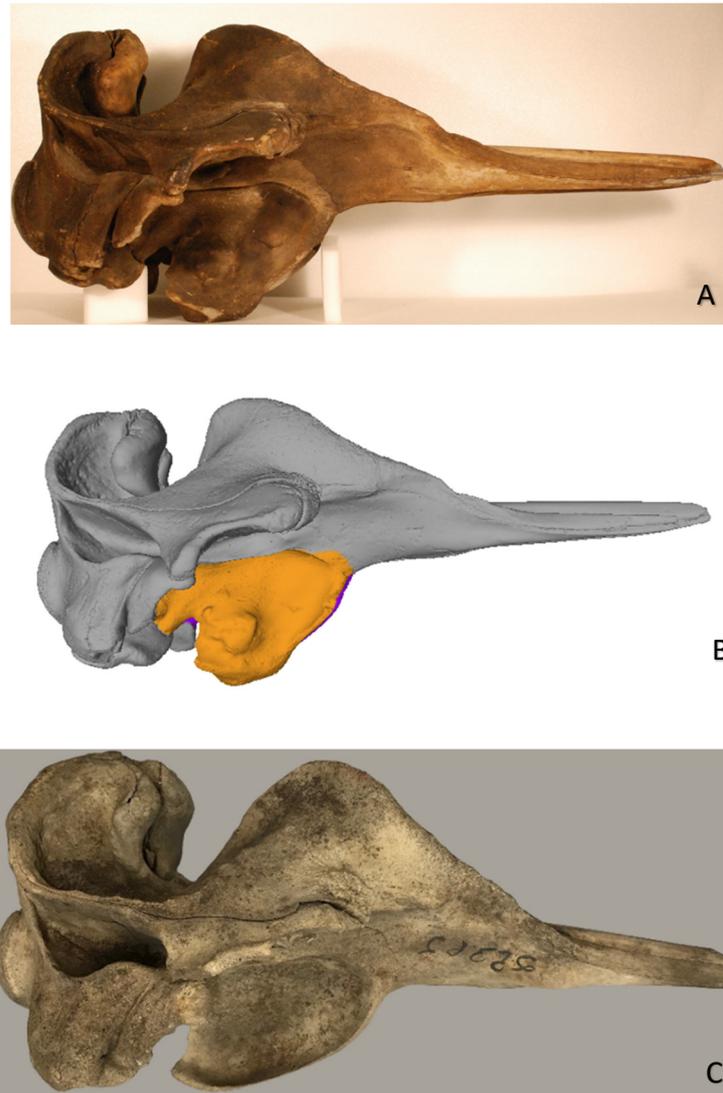
The condylobasal length (CBL) of ANSP-3004 was 133.1 cm. Other measurements are provided in Table 1. Overall, the cranial dimensions of ANSP-3004, measured as % of CBL, were comparable to normal *H. ampullatus* skulls without osteopathy (see Table 1), with the exception of the pterygoid bones. Values for, respectively, ANSP-3004 and MCZ-25362, both adult females, were (in % CBL): length of left pterygoid (27.2 vs. 29.3), length of right pterygoid (29.7 vs. 29.2), and width of left pterygoid (3.4 vs 9.4). Only the width of the right pterygoid (15.9 vs. 8.5) was greater in ANSP-3004 due to the deformation.

The form and structure of the right pterygoid were abnormal (Figures 1 and 2). Its distal (palatal) extremity was strongly curved in a labial direction while its proximal (ventral-most) extremity was deformed by a large (143 x 125 mm), bulbous exostosis that extended laterally and medially, occluding the space between the pterygoids and partially obstructing the right nasal passage (Figs. 1, 3). There was also evidence of osteolysis exposing deep resorption lacunae in the posterior end of the osseous mass (Figure 3). The left pterygoid was thin (34 mm), and slightly displaced laterally (Figure 1).



**Figure 1.** (A) Ventral view of study specimen *Hyperoodon ampullatus* ANSP-3004; (B) surface model of this specimen and (C) in comparison with a ventral view of the normal skull of adult female *H. ampullatus* (MCZ-25362) from the Museum of Comparative Zoology, Mammalogy Department, Harvard University.

On the 3D model, much of the space of the right pterygoid sinus appeared filled with osseous tissue while the left pterygoid sinus was unobstructed (Figure 1B). To what degree adjacent cranial bones, i.e., vomer, mesethmoid, ectocmoids, sphenoid, and (right) palatine, were affected could not be determined without (destructive) osteohistology and hands-on examination by (all) authors.



**Figure 2.** (A) Right lateral view of study specimen northern bottlenose whale *Hyperoodon ampullatus* ANSP-3004; (B) single surface scan model of this specimen showing deformation of the right pterygoid bone (orange); (C) lateral view of an adult female *H. ampullatus* (MCZ-25362) with normal pterygoids at the Museum of Comparative Zoology, Mammalogy, Harvard University.



**Figure 3.** Osteopathy of the right pterygoid bone in *Hyperoodon ampullatus* ANSP-3004: (Left) Occipital view of the upturned skull with (anterior) the bulbous exostosis seen protruding from the right

pterygoid; (Right) close-up view of the osseous mass exposing resorption lacunae, apparently from osteolysis.

Based on available observations, ANSP-3004 presented a marked ventral cranial malformation linked to a severe bulbous exostosis enveloping the right pterygoid, of unknown aetiology.

**Table 1.** Cranial measurements of female *Hyperoodon ampullatus* ANSP-3004 compared to two mature females (MCZ-25361 & RBINS-1503). NA= not available.

		ANSP-3004		MCZ-25361		RBINS-1503	
		Female		Female		Female	
	Measurements	Adult		Adult		Adult	
		in cm	in % CBL	in cm	in % CBL	in cm	in % CBL
1	Condylobasal length (CBL)	133.1	100.0	96.1	100	142	100
2	Greatest length of rostrum	83.9	63.0	53.8	56	93	65.5
3	Length, tip rostrum to anterior margin superior nares	100.4	79.9	72.4	75.3	98	69.0
4	Width of rostrum in apices of antorbital notches	36.6	27.5	24	25	35.3	24.9
5	Greatest breadth of skull at preorbital processes	68.2	51.3	49.2	51.2	55	38.7
6	greatest breadth of skull at postorbital processes	66.5	50.0	53.7	55.9	68	47.9
7	greatest breadth of nasal bones	28.1	21.1	23.7	24.7	27.5	19.4
8	Greatest breadth of occipital condyles	26.0	19.5	20.2	21.1	23.2	16.3
9	Height of skull, maxillary crests to most ventral point on pterygoids	56.4	42.3	40.5	42.1	52	36.6
10	Height of skull, vertex to most ventral point on pterygoids	50.5	38.0	41.8	43.5	55	38.7
11	Length orbit on frontal	16.4	12.3	13.5	14.5	NA	
12	Length right pterygoid	29.7	22.3	29.2	30.4	NA	
13	Width right pterygoid	15.9	11.9	8.5	8.8	NA	
14	Length left pterygoid	27.2	20.4	29.3	30.5	NA	
15	Width left pterygoid	3.4	2.5	9.4	9.8	NA	
16	Largest width both pterygoids	18.7	14.1	17.6	18.3	NA	
17	Greatest breadth of skull across zygomatic processes of squamosals	62.6	47.1	49	51	NA	
18	Tip of rostrum to most posterior wing of pterygoid	101.9	76.6	73.2	76.2	NA	
19	Tip of rostrum to most anterior extension of pterygoid	73.1	54.9	45.2	47	NA	

Lesions of the skull are poorly documented in the Ziphiidae family, with only one brief mention of osteolysis of the rostrum tip (premaxillary-maxillary bones) in an adult male Peruvian or lesser beaked whale *Mesoplodon peruvianus* Reyes, Mead and Van Waerebeek, 1991 stranded in Peru and curated at the Museo de Delfines, Lima, as MJE-001 (Montes et al. 2004, Reyes & Van Waerebeek 2018). The case described here represents the first record of an osteopathy of the pterygoids in ziphiids. Nematodes of the genus *Crassicauda* commonly infest the cranial sinuses of several Delphinidae species and cause trabecular or basket-like lytic lesions in the pterygoids, referred to as crassicaudiasis (Raga et al. 1982, Van Bresseem et al. 2020). However, the pathology observed in ANSP-3004 bears no resemblance to those. Besides, these helminth parasites have never been reported in the cranial sinuses of Ziphiidae, although they have been found in their vascular and genito-urinary systems (Tajima et al. 2015, Díaz-Delgado et al. 2016). A possible condition that may explain the osteopathy documented in the right pterygoid of ANSP-3004 includes osteoma, a benign, slow growing tumor that is 'histologically similar to ossifying fibroma, fibrous dysplasia, heterotopic ossification and exostosis' (Blood & Studdert 1999). In veterinary practice, osteomas are seen most commonly on jaws and in the nasal sinuses of horses and cattle (Blood and Studdert 1999). The latter (Bovinae) are closely related to Cetacea phylogenetically and share the same Order (Artiodactyla). Chronic osteitis following parasitic, fungal or bacterial sinusitis (Dagleish et al. 2007, Belda et al. 2018), or a combination thereof, may have contributed to exostosis formation, but is not thought to be the primary aetiology. A definitive diagnosis could not be reached as destructive sampling and histologic analysis of the exostosis was not permitted on this intangible, historical specimen.

The thick and robust pterygoid bones of beaked whales enclose large sinuses, each approximately a litre in volume in *H. ampullatus* (Scholander 1940), lined with a rich venous plexus that play an important role in deep diving (Rommel et al. 2006, Costidis & Rommel 2012). The malformation, including the severe bulbous exostosis in the right pterygoid, a partial obstruction of the right internal nare as well as a reduction of the left pterygoid width may have affected respiration and diving to some degree. However, the impact of this osteopathy on deep diving, and thus foraging (Rommel et al. 2006), appeared still inconsequential at the time of capture, considering that the female was able to nurse a calf. No other data were available that would allow an assessment of the general health status of both mother and calf.

While case studies as this one are very useful because yielding initial insights, what is needed are systematic future studies of diseases and traumas in representative samples of beaked whale skeletal material, available in many marine mammal collections. Such research should provide insights on the aetiology, prevalence and severity of ziphiid osteopathies, and help elucidate individual and potential population impact.

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**Conflict of interest:** The authors declare no conflicting interests related to any aspect of this case report.

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