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Beaked whales with rostrum deformities: Implications for survival and reproduction

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Beaked whales, members of the family Ziphiidae, are thought to be suction feeders (Heyning and Mead 1996). With the exception of the Shepherd's beaked whale (*Tasmacetus shepherdi*), all beaked whales have a reduction in the number of erupted teeth. In their upper jaws, teeth are absent or vestigial; only one or two pairs of teeth are found in the lower jaws, and usually erupt only in adult males, where they are thought to function primarily for combat between males (Mead 2002). Beaked whales also have two throat grooves that allow them to stretch and expand their throat, and a mobile tongue that can be retracted quickly, creating a drop in pressure that would suck prey into their mouths (Heyning and Mead 1996). Most of the information on diet of beaked whales comes from analyses of stomach contents of stranded individuals (MacLeod *et al*. 2003). They are believed to feed mainly on cephalopods (*e.g*., Lefkaditou and Poulopoulos 1998, Blanco and Raga 2000, Santos *et al*. 2001, MacLeod *et al*. 2003), although fish and crustaceans also play an important role in the diet of these whales, especially in some *Mesoplodon* species (Debrot and Barros 1994, Santos *et al*. 2007, Wenzel *et al*. 2013). With such a specific diet and feeding strategy, the rostral anatomy of beaked whales is considered a key aspect in feeding success. Here we report on several beaked whales with rostral malformations, including information on their sighting histories, suggesting that even with major deformities of the rostrum, beaked whales appear to be able to feed and reproduce successfully.

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Information was obtained on beaked whale rostral deformities observed during sightings from both research cruises and whale watching operations for two species, and from a stranding of a third species. Sightings occurred in the oceanic archipelagos of Madeira (northeast Atlantic, 32°N, 17°W), Canary Islands (northeast Atlantic, 28°N, 16°W), and Hawai'i (central North Pacific, 19°–20°N, 156°W), while observation of the stranded whale occurred in the Canary Islands. Age class and sex of sighted individuals was based on the type and extent of scarring on the body (McSweeney *et al*. 2007), time between first and last sightings and associations with calves, presence or absence of erupted teeth in the lower jaws, relative size in the field, and genetic analysis.

In Madeira, a Blainville's beaked whale (*Mesoplodon densirostris*) with a deformed rostrum was sighted in two consecutive years (2012, 2013) (CIIMAR-Madeira, catalog no. Md_OOM_017). The whale presented a displacement of the rostrum to the right of the midline, with the tip extending ventrally beyond the mandible (Fig 1a). Although we do not have detailed information about group size in these two sightings, from examination of the available photographs the individual was always seen with others. This individual was not very scarred and it lacked erupted teeth, but based on observations in the field it appeared to be adult sized, thus likely was an adult female. Beaked whales in Hawai'i accumulate scars from cookie-cutter sharks (*Isistius* sp.) over time, and thus the extent of scarring can be used to determine age class (McSweeney *et al*. 2007, Baird 2016). Individuals in Madeira do not appear to be bitten by cookie-cutter sharks. While there is a single record of a capture of cookie-cutter shark in Madeiran waters (Cadenat and Blache 1981, Muñoz-Chápuli *et al*. 1988), none of the 62 beaked whales identified in the Oceanic Observatory of Madeira catalog (unpublished data) had such scars, and thus they cannot be used for identification or age class determination.

In the Canary Islands, an adult female Cuvier's beaked whale (*Ziphius cavirostris*) was seen with a rostral deformity in 2011.[2] In this case the whale presented a reduced upper jaw with the tip of lower jaw displaced dorsally (Fig. 1d). The individual was seen with one other individual and appeared to be in good body condition, but has not been resighted.

In Hawai'i, two adult female Blainville's beaked whales were documented with rostral deformities. One (Cascadia Research Collective [CRC] catalog no. HIMd025) was seen across a period of 21 yr (1991–2012). Head photos of HIMd025 were not available until 2002, when the rostral deformity was first documented. This animal presented a lateral displacement of the upper jaw to the left (Fig. 1b). There were no subsequent changes to the rostrum based on head photos available through 2012. This individual was seen in groups that ranged from 4 to 11, and was thought to have had two calves (based on close association of small juveniles) during the span from 2002 to 2012. The other (CRC catalog no. HIMd026) was first documented in 2002 and 2003 with head photos showing no rostral deformity, but when next seen in 2012, the anterior portion of the rostrum angled to the left (Fig. 1c). There were no subsequent changes to the rostrum based on head photos available through 2016. In six sightings since it was first seen in 2012 with the rostral deformity, it was seen in groups of 3–5 individuals (most recently in 2016). Photographs of the rostrum are available for 119 Blainville's beaked whales in the CRC photo-identification catalog

[2]Personal communication from Chistoph Schmitt, Excursiones Tina E-38870 Valle Gran Rey, La Gomera, Canary Islands, 5 March 2009.

Figure 1. Images of the sighted animals with deformities: (a) Blainville's beaked whale from Madeira Island, (b) and (c) Blainville's beaked whale from Hawai'i, (d) Cuvier's beaked whale from the Canary Islands, and (e) and (f) Cuvier's beaked whale from Hawai'i. All are known (b, c, d, e) or thought (a, f) to be adult females.

(see McSweeney *et al.* 2007); thus, the two individuals with rostrum deformities represent 1.7% of the individuals in the catalog. Based on individuals that are known or suspected to be females ($n = 48$), they represent 4.2%. Two Cuvier's beaked whales with a rostral deformity were seen in Hawai'i. An adult female Cuvier's beaked whale in Hawai'i (catalog no. HIZc062) with a rostral deformity was seen in 2009 and 2012. This individual was missing the entire upper jaw (Fig. 1e). The whale was seen associated with a juvenile on the first occasion and in association with a calf on the second sighting. Another Cuvier's beaked whale with a rostral deformity was sighted alone once in 2011 (catalog no. HIZc075). The whale had a rostrum shorter that normal with enlarged mandibles at the end slightly bent over to the right (Fig. 1f). Based on scarring this whale was thought to be a subadult or a young adult, and was determined to be a female, using genetic analysis of a biopsy sample obtained (Table 1).

One stranded northern bottlenose whale (*Hyperoodon ampullatus)* from the southeast coast of Fuerteventura in 1988 was also documented with a rostral deformity. The

Table 1. Sighting information on the six beaked whale individuals and type of deformity observed. ID#: Local id of the individual in the institution's database. Md: *Mesoplodon densirostris*; Zc: *Ziphius cavirostris*; CRC: Cascadia Research Collective.

ID#	Location	Species	Date	Source	Group size	Description
Md_OOM_017	Madeira	Md	27 July 2012	Raquel Marques	—	Upper jaw bent over to the right
Md_OOM_017		Md	27 June 2013	Nicolau Abreu	—	Upper jaw bent over to the right
Md_OOM_017		Md	22 July 2013	Claudia Gomes	—	Upper jaw bent over to the right
—	Canary Islands	Zc	25 May 2011	SECAC	2	Reduced upper jaw
HIMd025	Hawai'i	Md	18 June 1991	Dan J. McSweeney	—	No head photos
HIMd025		Md	30 November 1994	Dan J. McSweeney	—	No head photos
HIMd025		Md	4 April 1995	Dan J. McSweeney	—	No head photos
HIMd025		Md	4 May 1997	Dan J. McSweeney	—	No head photos
HIMd025		Md	24 September 2002	CRC	9	Upper jaw bent over to the left
HIMd025		Md	7 March 2003	Masa Ushioda	—	Upper jaw bent over to the left
HIMd025		Md	7 May 2003	CRC	7	Upper jaw bent over to the left
HIMd025		Md	19 May 2007	Tom Bottrell	—	Upper jaw bent over to the left
HIMd025		Md	2 September 2007	Deron Verbeck	—	Upper jaw bent over to the left
HIMd025		Md	2 April 2008	Deron Verbeck	—	Upper jaw bent over to the left
HIMd025		Md	10 July 2008	CRC	11	Upper jaw bent over to the left
HIMd025		Md	13 July 2008	CRC	9	Upper jaw bent over to the left
HIMd025		Md	28 August 2008	Dan J. McSweeney	—	Upper jaw bent over to the left
HIMd025		Md	4 September 2008	Dan J. McSweeney	—	Upper jaw bent over to the left
HIMd025		Md	12 July 2011	Pacific Islands Fisheries Science Center	—	Upper jaw bent over to the left
HIMd025		Md	13 July 2011	Stacia Goecke	—	Upper jaw bent over to the left
HIMd025		Md	8 May 2012	CRC	4	Upper jaw bent over to the left
HIMd026		Md	24 September 2002	CRC	9	Upper jaw not bent
HIMd026		Md	7 May 2003	CRC	8	Upper jaw not bent
HIMd026		Md	19 May 2012	Dan J. McSweeney	4	Upper jaw bent to left
HIMd026		Md	19 May 2012	CRC	3	Upper jaw bent to left
HIMd026		Md	23 May 2012	CRC	4	Upper jaw bent to left

(Continued)

Table 1. (Continued)

ID#	Location	Species	Date	Source	Group size	Description
HIMd026		Md	18 April 2015	CRC	5	Upper jaw bent to left
HIMd026		Md	7 March 20 16	Dan J. McSweeney	3	Upper jaw bent to left
HIMd026		Md	5 April 2016	Dan J. McSweeney	3	Upper jaw bent to left
HIMd026		Md	25 April 2016	Deron Verbeck	5	Upper jaw bent to left
HIZc062		Zc	23 April 2009	CRC	2	Missing upper jaw
HIZc062		Zc	20 May 2012	CRC	2	Missing upper jaw
HIZc062		Zc	20 May 2012	CRC	2	Missing upper jaw
HIZc075		Zc	19 August 2011	CRC	1	Shorter rostrum with mandibles bent over to the right

Figure 2. Image of the stranded northern bottlenose whale *(Hyperoodon ampullatus)* female with a beak deformity. The reduced upper jaw and the exaggeratedly bent lower jaw are visible.

upper jaw measured only 5 cm while the lower jaw extended for 20 cm (Fig. 2). The deformed upper jaw had no signs of trauma and it was concluded that the malformation was congenital. The stomach contents were examined and a single cephalopod beak was found. This young female was part of an atypical mass stranding, together with two Cuvier's beaked whales, during a naval exercise with active sonar, as described by Martín *et al*. (2004).

The beaked whales mentioned in this study have severe deformities of the rostrum that could potentially interfere with their capability of feeding successfully. The fact that all of the whales were adults or young adults and four of the six whales were seen in several years confirms the survival of individuals with such rostral deformities over extended periods. Five of the six individuals were seen with one or more other conspecifics, typical for the social groupings of both Blainville's and Cuvier's beaked whales (Baird 2016). The cause of death of the northern bottlenose whale was likely related to the naval exercises occurring at the same time in the area where the stranding occurred (Martín *et al*. 2004), and not because it was incapable of feeding. Apart from the Blainville's beaked whale HIMd026 and the stranded northern bottlenose whale, it is unknown whether the deformities described in the other whales are congenital or acquired. Many causes can be responsible for acquired malformations in cetaceans: trauma caused by intraspecific interactions including play, competition, or adult–juvenile interactions, interspecific interactions such as predation, or anthropogenic factors, including entanglement and ship strikes (Evans and Raga 1987; Cox *et al*. 1998, 2006; Patterson *et al*. 1998; Wells *et al*. 1999; Gulland *et al*. 2001; Dunn 2002; Campbell-Malone *et al*. 2008). Regardless of the causes, these deformities did not seem to interfere with the individual's capacity to feed. The whales had robust body size and seemed healthy when compared to others individuals of the same group or in the same population. Although we cannot confirm the ability of these whales to hunt at depth successfully, based on the stomach contents found in the northern bottlenose whale, we can assume that they feed upon the same prey as the other individuals of their species. This seems to confirm that the bent upper jaws and even the absent upper jaws reported here (see also Baird 2016) do not affect their

capability to feed, presumably using suction. Sperm whales (*Physeter macrocephalus*), like beaked whales, presumably prey at substantial depths using suction (Werth 2004). Clarke (1956) reported several sperm whales with jaw deformities that were in good health condition, suggesting that a deformed jaw did not interfere with the feeding success of the whales. These findings indicate that either upper jaws do not play an important role in feeding or these individuals have adapted their feeding mode in order to survive. Recently, Wang *et al*. (2016) recorded an adult Indo-Pacific humpback dolphin (*Sousa chinensis*) missing its rostrum. The authors hypothesize that the individual, being incapable of snapping prey, may use a different feeding strategy, allowing the dolphin to survive for more than three years. The presence of calves also indicates that the Cuvier's beaked whale and Blainville's beaked whale from Hawai'i are not only capable of catching prey for their own survival but also of feeding and nurturing their calves. Given the typical group sizes and social structure of both species (Baird 2016), it is highly unlikely that these individuals are being supported and fed by other whales, as was the case of a killer whale (*Orcinus orca*) in Norway with a spinal deformity.[3] The killer whale, unable to hunt properly, was being supported by conspecifics, which allowed her to survive for at least 10 yr.

It is noteworthy that in the absence of a major malposition of the upper jaw, the lower jaw bends exaggeratedly upwards (Fig. 1). All the beaked whales were seen exhibiting normal behavior with no signs of distress or limitation. The fact that all the cases reported here are known or thought to be females is also important to highlight. The fact that the males have a different rostrum anatomy in these species, especially in *M. densirostris* (Mead 2002) lead us to speculate that contrarily to females, the males have less capability to survive to adult age with major rostrum deformities. These observations provide useful information about the capability of three species of beaked whales to survive and reproduce even when exhibiting deformities that could impair feeding or ultimately lead to death. To our knowledge, no evidence of such longevity and autonomy in cases of rostral deformities has been previously reported in these species. Although sightings are infrequent, it would be of value to obtain additional sightings of these individuals to further assess their longevity and reproductive history.

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[3]Personal communication from Heike Vester, Ocean Sounds e.V., Sauøya 33, 8312 Henningsvaer, Norway, 27 July 2016.

Literature Cited

Baird, R. W. 2016. The lives of Hawai'i's dolphins and whales: Natural history and conservation. University of Hawai'i Press, Honolulu, HI.

Blanco, C., and J. A. Raga. 2000. Cephalopod prey of two *Ziphius cavirostris* (Cetacea) stranded on the western Mediterranean coast. Journal of the Marine Biological Association of the United Kingdom 80:381–382.

Cadenat, J., and J. Blache. 1981. Requins de Méditerranée et d'Atlantique (plus particulièrement de la Côte Occidentale d'Afrique) [Sharks of the Mediterranean and the Atlantic (particularly of the west coast of Africa)]. Fauna Tropicale 21:1–330.

Campbell-Malone, R., S. Barco, P.-Y. Daoust, A. Knowlton, W. McLellan, D. Rotstein and M. Moore. 2008. Gross and histologic evidence of sharp and blunt trauma in North Atlantic right whales (*Eubalaena glacialis*) killed by ships. Journal of Zoo and Wildlife Medicine 39:37–55.

Clarke, R. 1956. Sperm whales of the Azores. Discovery Reports 28:237–298.

Cox, T. M., A. J. Read, S. G. Barco, *et al*. 1998. Documenting the bycatch of harbor porpoises in coastal gill net fisheries from strandings. Fishery Bulletin 96:727–734.

Cox, T. M., T. Ragen, A. Read, *et al*. 2006. Understanding the impacts of anthropogenic sound on beaked whales. Journal of Cetacean Research and Management 7:177–187.

Debrot, A. O., and N. B. Barros. 1994. Additional cetacean records for the Leeward Dutch Antilles. Marine Mammal Science 10:359–368.

Dunn, D. G. 2002. Evidence for infanticide in bottlenose dolphins of the western North Atlantic. Journal of Wildlife Diseases 38:505–510.

Evans, P. G. H., and J. A. Raga. 1987. The natural history of whales and dolphins. Christopher Helm, London, U.K.

Gulland, F. M. D., L. J. Lowenstine and T. R. Spraker. 2001. Noninfectious diseases. Pages 521–550 *in* L. A. Dierauf and F. M. D. Gulland, eds. CRC handbook of marine mammal medicine. CRC Press, Boca Raton, FL.

Heyning, J. E., and J. G. Mead. 1996. Suction feeding beaked whales: Morphological and observational evidence. Contributions in Science, Natural History Museum of Los Angeles County 464:1–12.

Lefkaditou, E., and Y. Poulopoulos. 1998. Cephalopod remains in the stomach content of beaked whales, *Ziphius cavirostris* (Cuvier, 1823), from the Ionian Sea. Rapport du 35e Congrès de la Commision Internationale pour l'Exploration Scientifique de la Mer Méditerranée 35:460–461.

MacLeod, S. D., M. B. Santos and G. J. Pierce. 2003. Review of data on diets of beaked whales: Evidence of niche separation and geographic separation. Journal of the Marine Biological Association of the United Kingdom 83:651–665.

Martín, V., A. Servidio and S. Garcia. 2004. Summary of the report on the atypical mass stranding mass of beaked whales in the Canary Islands. Pages 33–36 *in* P. G. H. Evans and L. A. Miller, eds. Proceedings of the Workshop on Active Sonar and Cetaceans, ECS Newsletter no. 42, special issue.

McSweeney, D. J., R. W. Baird and S. D. Mahaffy. 2007. Site fidelity, associations and movements of Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales off the island of Hawai'i. Marine Mammal Science 23:666–687.

Mead, J. G. 2002. Beaked whales, overview (*Ziphiidae*). Pages 94–97 *in* W. F. Perrin, B. Würsig and J. G. M. Thewissen, eds. Encyclopedia of marine mammals, 2nd edition. Academic Press, San Diego, CA.

Muñoz-Chápuli, R., J. C. Rel Salgado and J. M. De La Serna. 1988. Biogeography of *Isistius brasiliensis* in the North-Eastern Atlantic, inferred from crater wounds on swordfish (*Xiphias gladius*). Journal of the Marine Biological Association of the United Kingdom 68:315–32.

Patterson, I., R. Reid, B. Wilson, K. Grellier, H. Ross and P. Thompson. 1998. Evidence for infanticide in bottlenose dolphins: An explanation for violent interactions with harbour

porpoises? Proceedings of the Royal Society of London B: Biological Sciences 265:1167–1170.

Santos, M. B., G. J. Pierce, J. Herman, A. López, A. Guerra, E. Mente and M. R. Clarke. 2001. Feeding ecology of Cuvier's beaked whale (*Ziphius cavirostris*): A review with new information on diet of this species. Journal of the Marine Biological Association of the United Kingdom 81:687–694.

Santos, M. B., V. Martín, M. Arbelo, A. Fernández and G. J. Pierce. 2007. Insights into the diet of beaked whales from the atypical mass stranding in the Canary Islands in September 2002. Journal of the Marine Biological Association of the United Kingdom 87:243–251.

Wang, X., F. Wu, X. Ding and Q. Zhu. 2016. Record of an Indo-Pacific humpback dolphin (*Sousa chinensis*) without its upper rostrum in Xiamen Bay, Fujian Province, China. New Zealand Journal of Zoology 43:299–306.

Wells, R. S., D. J. Boness and G. B. Rathbun. 1999. Behavior. Pages 324–422 *in* J. E. Reynolds III and S. A. Rommel, eds. Biology of marine mammals. Smithsonian Institution Press, Washington, DC.

Wenzel, F. W., P. T. Polloni, J. E. Craddock, D. P. Gannon, J. R. Nicolas, A. J. Read and P. E. Rosel. 2013. Food habits of Sowerby's beaked whales (*Mesoplodon bidens*) taken in the pelagic drift gillnet fishery of the western North Atlantic. Fishery Bulletin 111:381–389.

Werth, A. J. 2004. Functional morphology of the sperm whale (*Physeter macrocephalus*) tongue, with reference to suction feeding. Aquatic Mammals 30:405–418.

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