Species review of Cuvier's beaked whale, *Ziphius cavirostris*

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Cuvier's beaked whale:

Ziphius cavirostris, the Cuvier's beaked whale or goose-beaked whale, was originally described by Cuvier in 1823 based on a partial cranium collected near Fos, France in 1804. Cuvier mistakenly originally identified the specimen as a fossil because he believed it to be "petrified" based on the extremely dense ossification of the rostrum. The trivial name *cavirostris* was based on the well-developed prenarial basin, or cavity, anterior to the bony nares. Turner (1872) later recognized this species as an extant species. Only males of this species develop this dense rostral ossification, as well as the sexually dimorphic prenarial basin not found in any other ziphiid (Fraser, 1942; True, 1910).

Ziphius exhibits a great deal of morphological variation, including regional differences in pigmentation patterns and osteological cranial characters (Heyning 1989). Heyning (1989) noticed no significant difference in total length between the sexes, with the average adult size being 613 cm. Average length at sexual maturity is 580 cm for females and 550 cm for males; mean length at birth is 270 cm. The genus *Ziphius* is monotypic (Dalebout et al. 2005, Heyning, 1989, Moore, 1968). Results from a molecular analysis of *Ziphius* samples taken from all oceans within its known distribution revealed overlapping haplotypes between populations, corroborating the validity of only one species (Dalebout et al. 2005). Ziphius is perhaps the most common of all beaked whales, with more reports of sightings and strandings than any other ziphiid species (Heyning and Mead 2009).

Distribution and Abundance:

Z. cavirostris has the most extensive distribution of all beaked whale species, occurring in deep waters worldwide and ranging from equatorial tropical to cold-temperate waters; they are not known to occur in the high latitude polar waters (Dalebout et al. 2005, Heyning and Mead 2009). Cuvier's beaked whales tend to be found in deep waters over and near the continental slope. They can often be found in waters where the steep continental slope occurs close to shore, such as around the Hawaiian Islands, the Bahamas, San Clemente Island, CA, and Canary Islands, or the Ligurian Sea, allowing for photo-identification and tagging studies, (e.g., Falcone et al. 2009, Johnson et al. 2004, McSweeney et al. 2007, Revelli et al. 2008). Resightings of individual whales in these areas occurred over multiple months and seasons and spanning as many as 15 years, suggesting long-term site fidelity in these areas, although seasonal movements throughout this species' range is largely unknown (McSweeney et al. 2007, Revelli et al. 2008).

Global abundance data are unavailable for this species, although the IUCN estimate a total worldwide population of at least 100,000. Based on information from studies of *Z. cavirostris* near the Hawaiian (Baird et al. 2009), Bahama (Claridge 2006), and Canary Islands (Aguilar de Soto 2006), as well as in the Bay of Biscay (Smith 2010), Ligurian Sea (Revelli et al. 2008), and San Clemente Island, California, USA (Falcone et al. 2009) where repeated sightings of individuals and tagging studies have been conducted, it appears that small, discrete populations of Cuvier's beaked whales exist. Preliminary population estimates of 56 whales in the waters around Hawaii (Baird et al. 2007) and 46 whales off El Hierro, Canary Islands (Aparicio et al. 2009) are based on mark-recapture studies from photo-identification of individuals. There is increasing evidence that small resident or year-round populations exist in various locations, and individual whales show site-fidelity within the populations. Therefore, any management plan

for these whales needs to be small scale at the population level and not the species or even ocean basin.

Ecology:

Numerous analyses of stomach contents have shown that cephalopods comprise the bulk of the diet of Cuvier's beaked whales worldwide (Foster and Hare 1990; Kovacic et al. 2010; Santos et al. 2001, 2007; See MacLeod et al. 2003 for a review of the literature on beaked whale diets). MacLeod et al. (2003) summarized data on stomach contents from 38 *Z. cavirostris* specimens throughout the range of this species; a total of 46 species of cephalopods representing 15 families were present, as well as two crustacean species, and stomachs rarely contained fish. Very few fish remains were found. The most prevalent cephalopod families found in the diet of Cuvier's beaked whales were Histioteuthidae, Gonatidae, Chiroteuthidae, Cranchiidae, Octopoteuthidae, Onychoteuthidae, Ommastrephidae, Pholidoteuthidae, and Brachioteuthidae, with Histioteuthid, Cranchiid and Gonatid species occurring in the greatest numbers and representing the most biomass.

Cuvier's beaked whales feed primarily on oceanic cephalopods (MacLeod et al. 2003, Santos et al. 2007). In the eastern North Atlantic, the primary prey species include *Taonius pavo*, *Mastigoteuthis schmidti, Octopoteuthis sicula, Teuthowenia megalops, Histioteuthis* spp., and *Gonatus spp.* (Santos et al. 2001, 2007). Six species of squid were found in the stomach of a *Z. cavirostris* stranded along the central Pacific coast of Japan, with *Gonatus* spp. and *Taonius pavo* being the most prevalent prey species (Ohizumi and Kishiro 2003). Fiscus (1997) reported on six families of squid in the stomach contents of a *Z. cavirostris* stranded on Amchitka Island, AK, and also found *Gonatus* spp. and *Taonius* sp. to be the predominant prey species. Squid from the families Gonatidae, Cranchiidae, and Chiroteuthidae were found in the stomach contents of Cuvier's beaked whales stranded in Alaska, including Kodiak Island and the Aleutian Islands, AK (Foster and Hare 1990, Kenyon 1961). Nishiwaki and Oguro (1972) noted that stomach contents of whales taken in waters less than 1000 m deep consisted primarily of cephalopod remains; however, they reported a transition in prey composition from cephalopods to "deep-sea fish" species, presumed by Ohizumi and Kishiro (2003) to be demersal fishes, in whales taken from waters greater than 1000 m. Based on the limited data available on beaked whale diets, *Berardius spp.* and *Mesoplodon spp.* tend to have a relatively higher proportion of fish in the diet, whereas *Z. cavirostris* appears to feed primarily on cephalopods (MacLeod et al. 2003, Santos et al. 2007).

Prey species and size suggest Cuvier's beaked whales dive to 300-1000 m to forage in the waters off Japan (Nishiwaki and Oguro 1972, Ohizumi and Kishiro, 2003). Many of the cephalopod species found in the diet of *Z. cavirostris* undertake daily vertical migrations, occurring closer to the surface during the night and moving to deeper waters during the day (Santos et al. 2007). However, much is still unknown about the life history and diurnal movements of many squid prey species of Cuvier's beaked whales. Despite the various patterns of vertical distribution among Cranchiid species, there is no evidence that these species undergo strong vertical movements; capture depths of specimens of *Taonius pavo* in waters off Hawai'i suggest a diel vertical migration does not occur in this species, with adult squid occurring primarily in waters deeper than 700 m (Young 1975, 1978; Roper and Young 1975). Among the Ommastrephidae, many oceanic species occur primarily in the upper few hundred meters during the day and night, with some individuals roaming to great depths, although species movements of these roamers are not known (Roper and Young 1975, Young 1978). *Brachioteuthis* spp. exhibit strong diel vertical migration, inhabiting deep waters (900-1000 m) during the day and ascending to the upper 200 m at night (Roper and Young 1975). Of the Chiroteuthids, some species of *Chiroteuthis* exhibit limited diel vertical migration and exhibit ontogenetic descent, occupying progressively greater depths during successive life history stages (Roper and Young 1975). Young (1978) reported on Chiroteuthis spp. daytime captures at depths between 700 and almost 1000 m, with captures at night occurring primarily within the first 200 m. *Histioteuthis* spp. tend to be diel vertical migrators, moving from depths of 400-800 m during the day to the upper 400 m at night (Roper and Young 1975, Young 1978). Wantanabe et al. (2006) also found several North Pacific *Histioteuthis* species to remain consistently distributed below 400 m, however, they considered these species to be non-migratory. Many *Gonatus* spp. are diel vertical migrators, shifting from 400-800 m depths during the day to either a slightly overlapping depth of 300-500 m in some species or shallower than 300 m in other species at night (Roper and Young 1975, Wantanabe et al. 2006). *Octopoteuthis* spp. and *Mastigoteuthis* spp. are believed to be diel vertical spreaders, with the former occupying depths of 200-400 m during the day and spreading out over depths from near the surface to about 500 m depth at night (Roper and Young 1975). Young (1978) reported on a species of *Octopoteuthis* exhibiting a vertical migration from daytime depths of around 650-750 m to nighttime depths between 100-200 m; *Mastigoteuthis* spp.

were captured between 675-800 m both day and night, although there was a slight trend of some species occurring primarily between 250-450 m at night.

Behavior:

Tagging studies in the Ligurian Sea and waters off the Canary Islands suggest Cuvier's beaked whales echolocate on their prey and forage at depth (Johnson et al. 2004, Madsen et al. 2005, Tyack et al. 2006). Maximum recorded dive depth and dive duration were 1888 m and 85 min, respectively, with echolocation foraging occurring in waters between 222 and 1885 m (Tyack et al. 2006). Average foraging dives were 1070 m deep and 58 min long, with approximately 30 attempts to capture prey each dive (Tyack et al. 2006). There was no indication of foraging during the series of shallower dives that typically followed deep foraging dives, and no vocalizations were detected from whales when they were within 200 m of the surface (Johnson et al. 2004, Tyack et al. 2006). Tagging studies of Cuvier's beaked whales off Hawai'i found these whales regularly dove for 48-68 min to depths greater than 800 m, with a maximum recorded dive depth of 1408 m (Baird et al. 2006). A similar dive pattern was found in this area, with extended periods of time spent within 50 m of the surface (66-155 min) before conducting a deep foraging dive (Baird et al. 2006). Little data exist in the literature to determine whether there is a difference in Cuvier's beaked whale dive behavior during the day versus at night, although Baird et al. (2006) did not observe any evidence of obvious differences in maximum dive depths between day and night from the one whale where the tag remained attached into the night.

Human Impact:

Direct takes and fisheries interactions:

Opportunistic takes of *Ziphius* occurred historically during the hunt for Baird's beaked whales, *Berardius bairdii*, off the North Pacific coast of Japan (Omura *et al.* 1955, Nishiwaki and Oguro 1972). There is no commercial hunt for *Ziphius*, the sale of products from this species still occurs in markets in Japan and South Korea, suggesting undocumented direct takes or bycatch of *Ziphius* still occurs in this area (Dalebout et al. 1998). Small numbers of direct takes of Ziphius have been documented in other areas such as the Lesser Antilles, Indonesia, Peru, and Chile (Reeves 1988, Jefferson et al. 1993, Rudolph et al. 1997, Van Waerebeek et al. 1999). Incidental takes of *Ziphius* have occurred historically in commercial fisheries off both the Pacific and Atlantic coast of the U.S., as well as the Mediterranean Sea, primarily in drift net fisheries (di Natale 1994, Henshaw *et al.* 1997, Heyning 1989, Julian and Beeson 1998). Use of acoustic pingers appears to have eliminated the bycatch of beaked whales in a California drift net fishery since their initial use in 1996 (Barlow and Cameron 2003, Carretta *et al.* 2008); however, occasional serious injuries and mortalities in fisheries still occur and some stranded beaked whales present with signs of potential entanglement (Waring *et al.* 2009, Carretta *et al.* 2009). There are two separate reports of live stranded Cuvier's beaked whales from the coast of South Carolina (USA); one was observed with a 7.5 cm metal longline hook penetrating the bone of the left lower jaw with line attached, and another with a rope attached to the tailstock with the rope cutting deep into the flukes (Smithsonian Institution Cetacean Distributional Database, accessed 27 May 2011).

Ocean noise:

Unusual mass mortality events, particularly those resulting from suspected or confirmed anthropogenic noise, have prompted an interest in understanding more about the physiology, behavior, and sensitivities of beaked whales (Cox *et al.* 2006; D'Amico et al. 2009; Fernandez *et al.* 2004, 2005; Filadelfo *et al.* 2009; Frantzis 1998; Simmonds and Lopez-Jurado 1991; U. S. Department of Commerce and U. S. Navy 2001; Rommel *et al.* 2006; Jepson *et al.* 2003). Shipping noise may disrupt the behavior of Cuvier's beaked whales (Aguilar de Soto et al. 2006). Atypical mass strandings consisting of multiple individuals and often mixed-species, including *Ziphius*, have occurred concurrent with the use of mid-frequency sonars and seismic exploration airguns, suggesting Cuvier's beaked whales are one of the species susceptible to certain anthropogenic sounds (Frantzis 1998, 2004; U. S. Department of Commerce and U. S. Navy 2001; Malakoff 2002; Jepson *et al.* 2003; Fernandez *et al.* 2004, 2005; Cox *et al.* 2006).

Cuvier's (*Z. cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales are the two species of beaked whales most commonly involved in mass strandings associated with sonar (D'Amico et al. 2009). Both of these species routinely dive to depths greater than 1000 m for a duration exceeding 1 h (Tyack *et al.* 2006), and both are

known to occur in the deep waters east of Andros Island in the Bahamas, an area known as the Tongue of the Ocean (Claridge 2006). This area was selected by Tyack *et al.* (2011) to conduct studies of the responses to tagged beaked whales to controlled exposures of tactical mid-frequency sonars, as well as playbacks of simulated sonar sounds, during multi-day naval exercises. No Cuvier's beaked whales were tagged during this study; however, tagged *M. densirostris* whales stopped echolocating during deep foraging dives, broke from foraging dives with long, slow ascents, and moved away from the area when exposed (Tyack *et al.* 2011). Whales returned to the study area 2-3 days after the sonar exercises ended, suggesting these sounds led to disruption of foraging and avoidance behavior. Results from this study support the growing consensus that exposure to military sonar may trigger a behavioral response that results in lethal stranding rather than death resulting from traumatic injuries caused by direct exposure to particular sound levels produced during sonar exercises (Cox et al. 2006, Tyack et al. 2011). Changes in dive behavior in response to sound exposure may result in injuries related to bubble growth during decompression (Cox et al. 2006, Tyack et al. 2011).

In a review of mass strandings of beaked whales reported between 1874 and 2004, D'Amico *et al.* (2009) found that 126 of the 136 mass stranding events occurred between 1950 and 2004, after the introduction and implementation of modern, high-power mid-frequency active sonar (MFAS). Only 2 of these 126 mass stranding reports contained details on the use, timing, and location of sonar relative to stranding location; ten other events coincided spatially and temporally with naval exercises that may have involved MFAS, 27 events occurred near a naval base or ship with no evidence of sonar use, and the remaining 87 events had no evidence for a link with any naval activity (D'Amico *et al.* 2009). Of the 126 beaked whale mass stranding events, 118 events involved a single species and 8 were mixed species events, all of which included *Ziphius* with at least one other ziphiid species (D'Amico *et al.* 2009). The largest percentage (45.8%; 54 events, 216 animals) of the single species mass strandings (n = 118) involved *Ziphius*, nearly half of which were reported in the Mediterranean Sea (Podesta *et al.* 2006, D'Amico *et al.* 2009). All beaked whale mass stranding events reported as associated with naval activities involved solely *Z. cavirostris* or mixed-species strandings involving *Z. cavirostris* and *Mesoplodon* spp. or *H. ampullatus* (D'Amico *et al.* 2009).

Marine debris (plastics):

Occasionally plastic is found in the stomachs of stranded beaked whales. Poncelet et al. (2000) reported on a Cuvier's beaked whale that stranded along the French Atlantic coast with several plastic bags in the stomach. Eight other records of stranded beaked whales, both males and females, with plastic found in the stomach contents were reported in the Smithsonian Institution Cetacean Distributional Database (accessed 27 May 2011). These whales stranded in Italy (1), Spain (2), and the United States (Florida, 2; South Carolina, 1; Virginia, 2), with the plastic debris including items such as a small piece of plastic, a plastic straw, saran wrap and tissue box plastic, as well as multiple plastic bags.

Conservation Status:

Ziphius cavirostris has been listed by the IUCN as "least concern" since 2008, although it was previously classified as data deficient (Taylor et al. 2008). Cuvier´s beaked whales are protected by the EU Habitat Directive and the U.S. Marine Mammal Protection Act and are listed in Appendix II of CITES.

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