Review of current knowledge on *Ziphius cavirostris* in the North Pacific and North Indian oceans, including identification of knowledge gaps and suggestions for future research

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1 INTRODUCTION

This working paper summarizes current knowledge of the species *Ziphius cavirostris* in the North Pacific and North Indian Ocean, and includes recommendations for future research.

2 TAXONOMY AND NOMENCLATURE

Scientific name: Ziphius cavirostris

Vernacular names: Cuvier's beaked whale; Goose-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. Initially, Cuvier mistakenly 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 the dense rostral ossification, as well as the sexually dimorphic prenarial basin not found in any other ziphiid (Fraser, 1942; True, 1910).

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).

3 DISTRIBUTION, POPULATION STRUCTURE AND MOVEMENTS

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 (Dalebout et al.

2005, Heyning and Mead 2009). In the North Pacific, Cuvier's beaked whales appear to be widely distributed, ranging from equatorial waters as to far north as the Gulf of Alaska and along the Aleutian and Commander Islands in the Bering Sea, and Sea of Okhotsk; they are not known to occur in the high latitude polar waters. Cuvier's beaked whales tend to be found in deep waters over and near the continental slope. They are commonly 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 the 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 each of these areas occurred over multiple months and seasons and spanned up to 15 years, suggesting long-term site fidelity, although seasonal movements throughout this species' range is largely unknown (McSweeney et al. 2007, Revelli et al. 2008).

Stranding records are known from waters in the western North Pacific, including the Philippine Sea, Sagami Bay, along the coasts of Taiwan, Japan, the Russian Commander Islands, ranging along the Aleutian Island chain of Alaska, and in the eastern North Pacific from Alaska, including both the Bering Sea and Gulf of Alaska, the U.S. west coast, Baja California, and the Gulf of California, Mexico, and Panama (Kenyon, 1961; Foster and Hare, 1990; Marine Mammal Database, National Museum of Science,Tokyo; Smithsonian Institution, Cetacean Distributional Database, accessed 04 June 2012). Strandings have also been reported from the Caroline Islands (Ponape), Hawaiian Islands, Palmyra Atoll, and in Saipan, Commonwealth of the Northern Mariana Islands (K. West, Hawaii Pacific University, pers. comm. 10 June 2012).

In the North Indian Ocean, strandings of Z. cavirostris have been reported throughout the Northern Indian Ocean, including the Arabian and Laccadive seas. Strandings have been reported from Masirah Island, Oman, Salomon Island in the Chagos Archipelago, Minicoy Atoll, the Maldives, Colombo, Sri Lanka, and Indonesia (Alling, 1986, Dammerman, 1926, Deraniyagala 1965, Smithsonian Institution, Cetacean Distributional Database, accessed 04 June 2012). Sightings have occurred in the Arabian Sea (Ballance and Pitman, 1998) and the Maldives (Ballance *et al.*, 2001).

Between 1945 and 2007, fourteen Cuvier's beaked whale strandings were recorded in San Diego County, California (USA), five of which were alive at the time of stranding (Danil et al. 2010). In the western North Pacific, there are 71 stranding records of *Z. cavirostris* in Japan between 1957-2010 (T. K. Yamada, unpubl. data), including strandings and bycaught animals, as well as several mass stranding records. Six mass strandings are included in this dataset for Japan, with the earliest mass stranding occurring in 1960, consisting of an adult male and pregnant female that initially stranded alive in Tokyo Prefecture and later died. *Z. cavirostris* is the most common cetacean to strand on Bering Island, with a total of 40 records between 1970-2012 (S. Formin, pers. comm., 30 April 2012). Twenty-one records of *Z. cavirostris* strandings have been reported in Alaska between 1947-2012 (NOAA Alaska Marine Mammal Stranding Database, unpubl. data, accessed 15 April 2012).

Based on information from studies of *Z. cavirostris* near the Hawaiian (Baird et al. 2009b), 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. A preliminary population estimate of 56 whales in the waters around Hawaii was derived from marked individuals sighted between 2003-2006 (Baird et al. 2009a). There is increasing evidence that small resident or year-round populations exist in numerous locations worldwide, and that individual whales show site-fidelity within these populations. Therefore, any management plan for these whales needs to be targeted to the smaller scale population level in contrast to a species-wide or ocean-basin approach.

Groups sizes of *Z. cavirostris* routinely sighted off the west coast of the island of Hawaii were small, typically ranging between 1-3 animals (Baird, 2010). Photo-identification data collected between 1990-2006 resulted in a minimum catalog of 33 distinctive individuals, including 13 adult males, 15 adult females; the remaining individuals were unknown sex (McSweeney et al. 2007). Resighting rates for distinctive individuals was 40%, and adult females were more frequently resighted long-term (McSweeney et al. 2007). Little is known about social organization for this species, as repeated associations between individuals have only been documented five times and over short periods of time, with the exception of a female and calf repeatedly sighted together over several years (McSweeney et al. 2007). Most small groups had only one adult male, although small groups consisting of two adult males, all of which included one or two adult females, have been observed on several occassions, with at least one group exhibiting probable competitive behavior between the adult males (McSweeney et al. 2007).

Based on movements of two adult female Cuvier's beaked whales tagged off the west coast of the island of Hawaii, one of which was a known resident of the local population, median water depths and distances from shore for the two animals were 2,389 m and 14.4 km (7.2 days) and 1,970 and 10.7 km (25.5 days) (Baird et al. 2010). Long (maximum 86.9 min.), deep (maximum 1,752 m) dives were recorded both day and night (Baird et al. 2010), and dive patterns were similar to those previously reported (Baird et al. 2006, 2009b). Slight diel differences are noted in diving parameters measured during the day and night, with animals spending more time at depths <100 m between foraging dives at night than during the day (Baird et al. 2008, 2010). Tagging studies from six different individuals tagged between 2006-2010 have demonstrated that *Z. cavirostris* remain strongly associated with the island of Hawaii for periods of weeks to months (Schorr et al. 2008, 2009; Baird et al. 2009a), suggesting the existence of a resident population. Long-term site fidelity evident from photo-identification data (McSweeney et al. 2007) and preliminary genetic evidence (Dalebout 2008) further supports the existence of an island-associated resident population that is potentially distinct from surrounding populations. Such small-scale movements need to be considered in management decisions and when measuring the potential impacts of anthropogenic activities on small local populations.

4 LIFE HISTORY PARAMETERS

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.

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). 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 that 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 species of squid prey eaten by Cuvier's beaked whales.

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 during 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 that 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 also 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. However, 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.

Long and Jones (1996) report on the first known record of white shark predation of *Z. cavirostris*, and noted that scavenging by white sharks is also known to occur on this species. McSweeney et al. (2007) report on an individual photographed off Hawaii with scarring from a large shark bite.

5 ABUNDANCE AND TRENDS

5.1 Abundance

Global abundance data are unavailable for this species, although the IUCN estimates a total worldwide population of at least 100,000 individuals. Very few estimates of density or abundance are avaiable primarily due to the rarity and difficulty in detecting and identifying beaked whales, and large-scale cetacean abundance surveys are often focused in areas where beaked whales do not typically occur, such as continental shelf waters (Barlow et al. 2006). Wade and Gerrodette (1993) estimated an abundance of 20,000 (CV=0.27) Cuvier's beaked whales in the eastern tropical Pacific based on surveys conducted from 1986-1990; however, this study assumed g(0) and included Beaufort sea states ranging from 0 to 5, so this is likely an underestimate. Barlow (1995) estimated an abundance of 1,621 (CV=0.82) based on a 1991 summer and fall ship suvey off the coast of California, using a g(0) of 0.84 to account for perception bias but did not account for availability bias. A second estimate of *Z. cavirostris* of 1,884 (CV=0.68) was reported by Barlow (2003) for the U.S. west coast based on surveys off California, Oregon, and Washington, which only included observations in Beaufort sea states 0-2 and included both perception and availability biases. These biases were used by Ferguson and Barlow (2001) in a re-analysis of all Southwest Fisheries Science Center eastern North Pacific ship survey data from 1986-1996, which resulted in an abundance estimate of 90,725 (CV=N/A). Barlow (2006) reported an abundance estimate of 15,242 (CV=1.43) *Z. cavirostris* in the U.S. EEZ waters around Hawaii based on 2002 Hawaii ship surveys.

A preliminary population estimate of 56 whales in the waters around Hawaii (Baird et al. 2007) is 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 worldwide, with individual whales showing site-fidelity within these populations.

5.2 Trends

No data exists on trends in abundance for any population of *Z. cavirostris.*

6 DIRECT REMOVALS

6.1 Directed takes

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). Although 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 that bycatch of *Ziphius* still occurs in this area (Dalebout et al. 1998). Small numbers of direct takes of *Z. cavirostris* have been documented in Indonesia (Jefferson et al. 1993).

6.2 Incidental takes

Incidental takes of *Ziphius* have occurred historically in commercial fisheries off the Pacific, primarily in drift net fisheries and including some takes in the High Seas Pelagic Driftnet Fisheries (di Natale 1994, Henshaw *et al.* 1997, Heyning 1989, Julian and Beeson 1998, Yatsu et al. 1994). 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 (Carretta *et al.* 2012). Forney (2009) reports on one unidentified cetacean taken in the deep-set longline fishery in international waters, which may have been a Cuvier's beaked whale, although there is no data to confirm this identification.

In a summary of cetacean strandings for San Diego County, California (USA) between 1851-2008, Danil et al. (2010) reported on two live adult Cuvier's beaked whales that became entangled in a fishing net off La Jolla Cove in 1963. One animal was freed alive and the other died after disentangling itself; another Cuvier's beaked whale stranded alive in Del Mar that same day and died on the beach, but no evidence of human interaction was reported.

Three records of bycaught *Z. cavirostris* are reported as being taken in a salmon drift net fishery (1) and setnet (2) in Japan in 1985-1986, and a single animal was reported as bycatch due to collision with a fishing vessel in 1957 (T. K. Yamada, unpubl. data).

Baker et al. (2006) used DNA-surveillance techniques to identify whalemeat products sold in the markets of the Republic of (South) Korea between 2003 and 2005, revealing meat from Cuvier's beaked whales was among the products available. No commercial or scientific whaling program exists in Korea; therefore, the only legal source of these products was assumed to be incidental fisheries mortalities reported by the government to the IWC.

7 OTHER ACTUAL AND POTENTIAL THREATS

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, Hooker 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. 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 from various locations in

Europe and the United States in the Smithsonian Institution Cetacean Distributional Database (accessed 04 June 2012). Marine debris, particularly plastics, are a problem in all oceans and should be considered in conservation efforts for this species worldwide.

8 STATUS

Ziphius cavirostris is 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 listed in Appendix II of CITES.

9 RECOMMENDATIONS

- Increased effort into obtaining species-level identifications; do not use Mesoplodon spp. as a management unit
- Species-level management is desirable, and a high priority should be placed on finding means to obtain species-specific abundance information.
- Photo-identification and tagging efforts to monitor movement patterns (seasonal as well as ranges); determination of population sizes/ movements of individuals, identifying whether site-fidelity to specific habitats
- Consider the use of pingers where longline bycatch a concern
- Increased communication and coordination between research community, government agencies, and industry regarding activities in known beaked whale habitat. This should include but not be limited to: pre-activity monitoring, monitoring and mitigation efforts during activities, and post-operational monitoring, including observations and presence/ absence data, sightings (aerial and/ or ship-based), acoustic monitoring, increased monitoring for strandings, etc.
- Better information on population structure of oceanic *Z. cavirostris* as well as those around archipelagos ; this should include genetics, morphometrics, photo-identification, acoustics, and long-term tagging studies, as well as habitat requirements and life history
- Use of passive acoustics concurrent with surface observations
- Differentiate among the potential effects of various anthropogenic sources of noise - determine effects of various source levels, frequencies, and signal types
- Increase observer training for making at-sea identification of beaked whales

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