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Review

Navy sonar and cetaceans: Just how much does the gun need to smoke before we act?

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ABSTRACT

Cetacean mass stranding events associated with naval mid-frequency sonar use have raised considerable conservation concerns. These strandings have mostly involved beaked whales, with common pathologies, including "bubble lesions" similar to decompression sickness symptoms and acoustic traumas. However, other cetacean species have also stranded coincident with naval exercises. Possible mechanisms for the strandings include a behavioral response that causes deep divers to alter their diving behavior, which then results in decompression sickness-like impacts. Current mitigation measures during military exercises are focused on preventing auditory damage (hearing loss), but there are significant flaws with this approach. Behavioral responses, which occur at lower sound levels than those that cause hearing loss, may be more critical. Thus, mitigation measures should be revised. A growing number of international bodies recognize this issue and have urged increasing scrutiny of sound-producing activities, but many national jurisdictions have resisted calls for increased protection.

1. Introduction

In March 2000, at least 16 whales of three species stranded on beaches and in mangroves in the northern Bahamas, within a short period of time but spread out over several kilometers and islands. US Navy vessels were transiting through the area at the same time. Researchers studying beaked whales in the Bahamas suggested that this unusual stranding event resulted from the use of high-intensity active sonar by these vessels (Balcomb and Claridge, 2001). A US government investigation (Anonymous, 2001) later concluded that the use of mid-frequency active sonar[1] by Navy ships was the most likely cause of the strandings and of the injuries sustained by the animals. The effects of active sonar on marine mammals have subsequently become a major welfare and conservation issue (Marine Mammal Commission, 2007; Weilgart, 2007).

The Bahamas incident was not the first mass stranding of cetaceans that had been linked to naval activities (Frantzis, 1998, 2004; Frantzis and Cebrian, 1999; Simmonds and Lopez-Jurado, 1991; Van Bree and Kristensen, 1974). However, it was certainly the most publicized and the first with sufficient post-event evidence gathered to build a strong scientific case for causation, mainly because of the ongoing long-term study of cetaceans in the area. Crucially, one of the biologists on site was a former member of the US Navy who, as a result of his knowledge of underwater acoustics and the particular nature of the injuries sustained by the whales, made the link between the strandings, the presence of naval vessels and the possible effects of sonar use on cetaceans (Balcomb and Claridge, 2001).

2. Military exercise-related beaked whale mass strandings and events

As a result of the international publicity surrounding the Bahamas situation, scientists have examined previous patterns of mass strandings and military activities around the world. A considerable number of beaked whale mass stranding events have occurred concurrently with naval activities in several countries, although the use of mid-frequency sonar during these exercises cannot be

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[1] The sonar system involved was AN/SQS-53C a US Navy tactical mid-frequency sonar, producing 'pings' primarily in the 2.6–3.3 kHz frequency range at a source level of approximately 235 dB re 1 μPa.

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confirmed in all cases (Brownell et al., 2004; Espinosa et al., 2005; Fernández et al., 2005b; Fernández, 2006; Freitas, 2004; Hildebrand, 2005a; ICES, 2005; Martin et al., 2004; Podesta et al., 2006; Taylor et al., 2004; Van Bree and Kristensen, 1974). Many of these events have taken the form of an "atypical" mass stranding (including the stranding in the Bahamas in 2000), which involves more than two animals, stranding approximately simultaneously but not in the same location (Brownell et al., 2004; Frantzis, 1998; International Whaling Commission, 2005a). Such events appear to be reliable indicators of localized intense noise pollution.

Worth specific note are at least eight mass strandings of beaked whales that have been associated with military exercises around the Canary Islands (Fernández et al., 2005b; ICES, 2005; Taylor et al., 2004). The most recent of these, in July 2004, involved four Cuvier's beaked whales, *Ziphius cavirostris,* and coincided with the naval exercise "Majestic Eagle", which was conducted 100 km to the north of the islands in the week prior to the beaked whale carcasses being discovered (Espinosa et al., 2005; Fernández et al., 2005b). Fernández et al. (2005b) considered it highly probable that these animals died at sea, rather than stranding live and then dying onshore. This increases the concern that additional animals to those found beached may be affected during similar events and may die in open water, but are not being discovered and examined (Fernández et al., 2005b).

The possibility of this "hidden" mortality is not surprising. While it is widely accepted that carcass detection rates can be quite low in wild populations of terrestrial animals, and thus the discovery of a single body should always be considered indicative of a wider problem (pp. 14–15, Wobeser, 1994), this same logic has not been applied by managers to the issue at hand. This is troubling, as carcass detection rates are likely to be lower still in the marine environment where human observers, especially on isolated stretches of coastline and at sea, are present more rarely than in many terrestrial environments and dead animals can quickly be scavenged upon, carried away by strong currents, or sink beneath the surface (Allison et al., 1991).

Japan appears to be another hot spot for strandings. US government scientists presented a paper at the 2004 meeting of the International Whaling Commission (IWC) that analyzed mass strandings of Cuvier's beaked whale and Baird's beaked whale, *Berardius bairdii,* in Japan from the late 1950s until 2004 (Brownell et al., 2004). The paper reported that there were 11 mass strandings (a total of 51 animals) involving these species, all of which occurred in Suruga Bay or Sagami Bay on the central Pacific coast of Honshu. Both of these bays are adjacent to the command base for operations of the US Navy's Pacific 7th Fleet (Brownell et al., 2004).

Nearby, in Taiwan, several cetacean strandings occurred from 24 February to 10 March 2004, including that of a ginkgo-toothed beaked whale, *Mesoplodon ginkgodens*. These strandings coincided with a joint US/Philippine military exercise, to the south of the island (Wang and Yang, 2004, 2006). Researchers conducted a necropsy of the intact head and partially cleaned post cranial skeleton of the beaked whale and revealed unusual injuries to structures that are associated with, or related to, acoustics and diving. Wang and Yang (2006) considered that "the freshness of the carcass, its discovery location and the coincidence of the event with nearby large-scale military exercises are suggestive that the energy source may have originated from these exercises" (p. 289). However, the Scientific Committee of the International Whaling Commission (IWC) was more emphatic, stating that the cranial lesions and trauma "suggest that this beaked whale died from acoustic or blast trauma that may have been caused by exposure to naval activities south of Taiwan" (p. 273, International Whaling Commission, 2005b).

More recently, an "atypical" mass stranding of Cuvier's beaked whales occurred off Almería on the Spanish coast in January 2006 (Fernández, 2006), which was coincident with a NATO naval exercise. A number of Cuvier's beaked whales have stranded on several of the western isles off Scotland through February and March 2008, dying at sea and washing ashore in a decomposed state (Dolman et al., 2008), further supporting concerns raised by Fernández et al. (2005b) of deaths at sea. Researchers are currently investigating potential naval activities in the vicinity.

3. Military exercise-related mass strandings of other species

Most attention has been focused on the beaked whale strandings concurrent with naval activities. However, while they do make up the majority of the casualties, several other species have stranded coincident with naval exercises (ICES, 2005; Nowacek et al., 2007; Weilgart, 2007). For example, a northern minke whale, *Balaenoptera acutorostrata*, was found in the 2000 Bahamas incident (Balcomb and Claridge, 2001).

In addition to beaked whales, short-finned pilot whales, *Globicephala macrorhynchus,* also stranded in the 2004 Taiwan incident (Wang and Yang, 2004). Similar strandings in coastal areas of southwest Taiwan occurred in February 2005, with two mass stranding events of live pygmy killer whales, *Feresa attenuata*, as well as a milling event[2] involving this species, with a group entering a shallow coastal harbor (Wang and Yang, 2006). A necropsy of one of the pygmy killer whales revealed hemorrhaging in the cranial tissues of the animal. Moreover, between 19 July and 13 August 2005, there were 22 further stranding events throughout Taiwan, involving several species[3] and a total of 25 animals, primarily along the northern coast of Taiwan (Wang and Yang, 2006). This spate of strandings is, to date, the greatest rate of cetacean strandings recorded for the country (Wang and Yang, 2006). During July, a naval exercise was being conducted by the Chinese military in the East China Sea, and in August, a joint Japanese/US Navy exercise took place, albeit at a considerable distance from Taiwan, off the coast of Okinawa and Guam (Wang and Yang, 2006). Tissues from six cetaceans from these stranding events were examined, and five were found with small bubble-like lesions (Wang and Yang, 2006), similar to those found in other military-related strandings (see below; Fernández et al., 2004, 2005b; Jepson et al., 2003).

Thirty-four short-finned pilot whales, one minke whale and two pygmy sperm whales, *Kogia breviceps,* stranded in the Outer Banks, North Carolina, between 15 and 16 January 2005 (Kaufman, 2005a). Coincident with the stranding, one US Navy vessel was known to have used sonar for seven minutes about 90 nautical miles southeast of the stranding area (Kaufman, 2005a). The government reported that the stranding had a number of features in common with other "atypical" sonar-related strandings, e.g., the wide distribution of animals, involving multiple offshore species, all stranding alive, and without evidence of common infectious or other disease process (Hohn et al., 2006).

Similarly, on 25 and 27 October 2005, mass stranding events occurred in Tasmania, Australia, involving approximately 145 long-finned pilot whales, *G. melas*. On investigation, it was found that the animals stranded during three separate periods, the first occurring six hours before the arrival of two Royal Australia naval vessels (Department of the Environment and Heritage, 2005). However, the second event began just over an hour after the vessels began using high frequency (50–200 kHz) sonar in the vicinity

[2] A "milling event" is when a group of cetaceans enters shallow water and begins to circle continually or move about haphazardly in a tightly packed group, with an occasional member breaking away and swimming toward the beach. See section below.

[3] These species included dwarf sperm whales, *Kogia sima*, striped dolphins, *Stenella coeruleoalba*, Blainville's beaked whales, *Mesoplodon densirostris*, and Longman's beaked whales, *Indopacetus pacificus*.