**Agenda Item 6.7:** **Disturbance by Military Activities**

**Letter by K. C. Balcomb to J. S. Johnson referred to in Document AC8/Doc.12(O)**
**Military Noise: A statement of concern from WDCS**

**Submitted by:** **The Whale and Dolphin Conservation Society**

ASCOBANS

***NOTE:***
**IN THE INTERESTS OF ECONOMY, DELEGATES ARE KINDLY REMINDED TO BRING THEIR OWN COPIES OF THESE DOCUMENTS TO THE MEETING**

Mr. J.S. Johnson
Attn: SURTASS LFA Sonar OEIS/EIS Program Manager
901 North Stuart Street, Suite 708
Arlington, VA 22203

Dear Mr. Johnson:

Thank you for sending a copy of the Final Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar. Since my comments to you on the Draft OEIS/EIS (O-26; Balcomb, November 12, 1999), I have had the unique opportunity to witness and study a mass stranding of whales and a dolphin caused by a US Naval Sonar Exercise in the Bahamas (Pirie, ltr. June 15, 2000). That incident unequivocally demonstrated the lethality of high-powered sonars, and it provided the opportunity to understand how sonar has been inadvertently killing whales in vast expanses of ocean around the world.

The killing is largely due to resonance phenomena in the whales' cranial airspaces that are tearing apart delicate tissues around the brains and ears. This is an entirely separate issue from auditory thresholds and traumas that the Navy has fixated upon. In my earlier comments, I questioned whether there *might* be a problem with injurious **resonance** phenomena created by the sonar system described in your OEIS/EIS; but, now I have seen the problem and can attest to the fact that there *is* massive injury to whales caused by sonar. This is not an exaggerated statement, and I am reasonably sure that the Navy knows that. Please allow me to explain what happens to the whales.

Resonance, as engineers well know, can dramatically contribute to shear forces that can be quite damaging – wings tear off airplanes, bridges gallop, and buildings collapse, etc. due to unanticipated resonance phenomena which can afterwards be explained by simple physics and mechanics. I wondered about tissue damage caused by resonance, and I specifically asked what the Navy calculations for lung resonance frequencies of a beaked whale were at various depths. [You sidestepped my question by responding generically to my comment with response 4-4.15]. Subsequent to my asking you about specific resonant frequencies and depths, I found that in 1998 NATO and the US Naval Undersea Warfare Center had already calculated the resonance frequency of airspaces in Cuvier's beaked whales (Ziphius cavirostris) to be about **290** Hz at 500 meters depth (page H2, SACLANTCEN M-133), which is almost precisely the middle frequency of LFA (**100-500** Hz) described in your OEIS/EIS! That information is quite important, with specific reference to Technical Report 3 of your DOEIS/EIS, wherein there are several citations of Navy sponsored studies that clearly demonstrated vestibular dysfunction (eg. dizziness, vertigo) and lung hemorrhage, etc. in laboratory animals exposed to LFA at their lung resonance frequency. In other words, the Navy has sufficient information available to know there is at least theoretically a very serious problem to whales from LFA for even brief periods of time.

The scientific and medical literature contains numerous examples of hemorrhagic injuries and death occurring in *humans* when they are inadvertently exposed to loud sound, particularly at their lung (airspace) resonance frequency. Undoubtedly such damage could also be demonstrated as occurring to whales if they could be tested and did not sink to the bottom of the ocean when they die.

The NATO report I referred to for resonance calculations was concerning the mass stranding of at least twelve Cuvier's beaked whales in Greece on 12 May, 1996 coincident with a NATO acoustic trial employing both LFA (450-700 Hz) and mid-frequency sonar (2.8-3.3 kHz). Superficially, in reading that report one might wonder whether either frequency range "caused" the whales to strand in Greece, since neither matched the **reported** resonance frequency in that instance for Cuvier's beaked whales' airspaces at an arbitrarily chosen 500 meters depth. However, also in that NATO report there were formulae of Minnaert and Andreeva presented that indicated the resonance frequency of airspaces can be calculated, within acceptable limits, from their volumes. Lung (airspace) volumes vary individually, and they also vary with depth, hence their resonance will vary accordingly. Nonetheless, the Navy used the formulae, and so did I. You could, too.

In order to perform these airspace resonance calculations correctly, one must know or take into account the following:

a. Boyle's Law PV=constant; therefore, lung (airspace) volume will decrease with increasing depth due to increasing pressure.

b. Lung (airspace) volume at the surface.

c. Functional anatomy of deep-diving beaked whales.

It is the volume of air in the individual pterygoid sacs and the laryngeal airspace, not the lungs, for which resonance should be calculated. Below about 100 meters depth virtually all of the air that was in the lungs at the surface is forced into laryngeal and cranial airspaces, wherein its volume *continues* to decrease with increasing depth until it has a total volume less than that of a football (compressed from, for example, a 100 liter lung full of air). The two largest of these remaining airspaces (pterygoid sacs or sinuses) are bilaterally adjacent to the earbones and the base of the brain (via the large foramen for the oversize VIII cranial nerve); and, their diminishing volume at depth is compensated for by retia mirabilia (a corpus cavernosum-like vascular network extending to the middle ear). [Envision the football-size airspace further squeezed to the size of a ping-pong ball with 1500 psi air pressure, now tucked between the ear bulla and the skull on each side of the head, thinly separated from a bag of blood next to it on the "soft" side.]

Following the Navy's example and the formulae of Minnaert and Andreeva, the frequencies of LFA (**and** powerful mid-frequency sonars) precisely match these cranial airspace resonance frequencies in these whales at predictable depths where they normally forage (500-1500 meters). [Now envision rapidly compressing and decompressing the ping-pong ball many times per second (sound and sonar travels as compressions and decompressions of the medium through which it is passing) until ultimately the amplitude is exaggerated by resonance.] The result is both astonishing and bloody. Many whales died due to this sonar resonance in Greece and in the Bahamas. Unfortunately, the Greek mass stranding incident passed into relative obscurity because the SACLANTCEN Bioacoustics Panel missed the crucial point of matching resonance in critical airspaces; and, because suitable specimen materials were not collected for discovering the problem.

At least seven beaked whales died in the Bahamas stranding that I witnessed; and, I had opportunity to examine four of the carcasses by necropsy. All of these whales that were examined evidenced similar lesions, i.e. hemorrhage in the acoustic regions of the cranium and mandible and in tissues adjacent to airspaces around the earbones (NMFS ltr. June 14, 2000). One fresh specimen that was examined by ultra high-resolution computerized tomography (UHR-CT) evidenced a subarachnoid hemorrhage (brain hemorrhage) with a direct path to the ear hemorrhage. This same specimen evidenced lung hemorrhage and laryngeal hemorrhage upon dissection. These hemorrhages are of the type of damage reported in laboratory animals exposed to LFA at lung resonance frequency, and they strongly corroborate the theoretical explanation of such injuries in these whales.

In order to approach this problem empirically, I prepared an endocast of the pterygoid sac of one of the Cuvier's beaked whale specimens from the Bahamas incident and determined that its volume closely matched the calculated volume used for the resonance formulae beginning around 170 meters depth where it would resonate at 470-590 Hz (within LFA range). At greater depths the resonance frequency of this pterygoid sac would increase to around 3.5 kHz at 1400 meters. Because most of the hemorrhage observed was in tissues adjacent to the pterygoid sac at its most posterior end where it is enveloped by retia mirabilia in a unique cul-de-sac of sesamoid bone and dense earbone that keep this space open during the deepest part of a dive, I consider the evidence compelling that resonance of this particular airspace is a real problem.

Again with respect to the Bahamas incident, I have read (Pirie ltr.) that the sonars employed were standard hull mounted and operating at 3.5 kHz @ 235 dB re 1uPa SL and 7.5 kHz @ 235 dB re 1uPa SL. What is important, of course, is the received level (RL) of these projected frequencies at the whales' receiving location when first impacted by the sound. I have been told that the Bahamas situation may have been complicated by oceanographic conditions and other factors that could have resulted in a "surface" sound duct in which most of the acoustic energy was trapped; but, I also **documented** that the whales stranded over an area 200 kilometers across! In this case, **if** the Navy report of several surface ships using "standard, hull-mounted sonar operating within normal mid-range frequencies, power outputs, and duty cycles" is true; **and, if** "within a range of 1000 meters from the ship in this surface duct, the sound level from the sonars dropped in intensity to less than 180 dB" is also true; **then**, it is not possible that all of the whales that stranded over such a huge area experienced received levels (RL) of these sonars **above** the alleged "safe limit" of 180 dB (not enough ships; too large an area). I conclude that the whales in the Bahamas incident were adversely and lethally impacted by sonar "pings" at received levels well below the 180 dB re 1uPa considered "safe" for whales, and this was due to the aforementioned resonance problem. These "pings" were of much shorter duration (1/10$^{th}$ second) than the proposed LFA "pings", I might add.

This sonar impact at received levels well below 180 dB is likewise well documented in the Greek incident reported in the NATO report SACLANTCEN M-133 (Annex G). The first whale to strand did so 40 km from the ship one hour after the acoustic trial commenced. If one takes into account how fast a beaked whale can swim (about 15 km per hour, maximum), it must have been at least 25 km from the ship when the first of its 238 four-second pings was transmitted! At that distance the RL was calculated by the Navy (NATO, Annex G) to be approximately 150 dB! The Bioacoustics Panel overlooked this important bit of evidence of received level for impact.

Therefore, based on two significant mass mortality events (Greece and the Bahamas) the body of evidence indicates that not only is resonance with LFA and sonar frequencies a problem for beaked whales, the sound pressure level of 180 dB RL is demonstrably "not safe", and it is probably not safe for other cetaceans (two minke whales and a dolphin also stranded in the Bahamas incident). Aversion and/or physiological damage **evidently and repeatedly** occurs in beaked whales at levels of somewhere between 150 and 180 dB RL (probably nearer the former) of either low frequency or mid-frequency sonar signals in the whales' normal habitat. Clearly, the impact of high-powered rapid-rise acoustic energy (such as sonar), particularly at airspace resonance frequency, on these animals is occurring at significant distances well beyond the current mitigation distance (1-2.2 km) used by the Navy. These impact distances can be easily calculated, and they are more like 20 to 100 kilometers, and more – well over the horizon of shipboard observers.

Cuvier's beaked whales were reasonably common in our field study area prior to the Bahamas incident; we had photo-identified about thirty-five of them, many repeatedly. We typically sighted small groups of these whales a dozen or more times per year in any month of the year. But since the Bahamas sonar incident we have seen this species only once in an entire year, and that was a sighting of two previously unidentified whales (i.e., new arrivals to our study area) about two months after the sonar exercise. None of the whales that were "rescued" have been seen again. In retrospect, it is probable that **all** Cuvier's beaked whales in the region when the naval exercise commenced were killed by the sonar, whether or not they were returned to sea by well-wishers pushing them off the shore. Considering the observed damage to the whales that stranded and died, and the short time period between stranding and death, the NMFS statement that "the whales died from stranding" is patently absurd. The whales that we observed swimming toward shore and stranding were only temporary survivors of an acoustic holocaust that can be likened to fishing with dynamite.

In summary, I consider the Navy's Final OEIS/EIS fails to justify the deployment of SURTASS/LFA with negligible or mitigable potential to harm marine mammals, therefore I recommend the No Action Alternative. In fact, there really is no Alternative 1- the Navy cannot reasonably mitigate the problem using visual, active acoustic or passive acoustic monitoring, nor can the Navy redesign the whales; at best it can only reconsider and perhaps redesign the SURTASS/LFA system. Considering that the facts of multiple whale deaths and their almost certain cause are now known to me, I cannot legally or morally support any recommendation to deploy SURTASS/LFA as proposed, and I trust that will be your conclusion as well.

Sincerely,

Kenneth C. Balcomb, III
Whale Biologist

Cc: Office of Protected Species, NMFS
CNO OP95
US Marine Mammal Commission
Distribution List